NEAR FIELD RECEIVING WATER MONITORING OF TRACE METALS IN CLAMS (*MACOMA BALTHICA*) AND SEDIMENTS NEAR THE PALO ALTO WATER QUALITY CONTROL PLANT IN SOUTH SAN FRANCISCO BAY, CALIFORNIA: 2003

U.S. GEOLOGICAL SURVEY

OPEN FILE REPORT 2004-1213

Prepared in cooperation with the
CITY OF PALO ALTO, CALIFORNIA

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **2004**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Near Field Receiving Water Monitoring of Trace Metals in Clams (MACOMA BALTHICA) and Sediments Near the Palo Alto Water Quality Control Plant in South San Francisco Bay, California: 2003**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Department of the Interior U.S. Geological Survey 1849 C. Street, NW Washington, DC 20240**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**84**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

NEAR FIELD RECEIVING WATER MONITORING OF TRACE METALS IN CLAMS (*MACOMA BALTHICA*) AND SEDIMENTS NEAR THE PALO ALTO WATER QUALITY CONTROL PLANT IN SOUTH SAN FRANCISCO BAY, CALIFORNIA: 2003

Edward Moon, Samuel N. Luoma, Daniel J. Cain, Michelle I. Hornberger and Carlos Primo C. David

---

U.S. GEOLOGICAL SURVEY

OPEN FILE REPORT 2004-1213

Prepared in cooperation with the
CITY OF PALO ALTO, CALIFORNIA

Menlo Park, California

U.S. DEPARTMENT OF THE INTERIOR
GALE NORTON, Secretary

U.S. GEOLOGICAL SURVEY
CHARLES GROAT, Director

For Additional Information
Write to:

Samuel N. Luoma, MS 465
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025

Copies of this report may be
obtained from the authors or

U.S. Geological Survey
Information Center
Box 25286, MS 517
Denver Federal Center
Denver, CO 80225

Table of contents

List of figures

List of tables

NEAR FIELD RECEIVING WATER MONITORING OF TRACE METALS IN CLAMS (*MACOMA BALTHICA*) AND SEDIMENTS NEAR THE PALO ALTO WATER QUALITY CONTROL PLANT IN SOUTH SAN FRANCISCO BAY: 2003

Edward Moon, Samuel N. Luoma, Daniel J. Cain, Michelle I. Hornberger and Carlos Primo C. David

Abstract

Trace element concentrations were analyzed on samples of fine-grained sediments and clams (*Macoma balthica*) collected from a mudflat one kilometer south of the discharge of the Palo Alto Regional Water Quality Control Plant in South San Francisco Bay. This report serves as a continuation of the Near Field Receiving Water Monitoring Study, which was started in 1994. The data for 2003, herein, are interpreted within that context. Metal concentrations in both sediments and clam tissue samples have been within the range of values produced by seasonal variability; however, copper and zinc, display continued decreases over the last decade. In 2003, copper in sediment was observed to drop below the ERL (Effects Range-Low) concentration for the third consecutive year and zinc concentrations never exceeded the ERL. Yearly average concentrations of copper, zinc and silver in *Macoma balthica* for 2003 are some of the lowest recorded since monitoring began in 1975. Mercury and selenium concentrations in sediments and clams at Palo Alto were similar to concentrations observed elsewhere in the San Francisco Bay.

Introduction

Sampling sediments and benthic organisms in an estuary is a common method used to determine spatial distributions and temporal trends of metal contamination. Sediment particles strongly bind metals, effectively removing them from solution. As a result, sediments may retain metals released to the environment. Thus, concentrations of metals in sediments serve as a record of metal exposure in an estuary, with some integration over time. Fluctuations in the record may be indicative of changes in anthropogenic releases of metals into the environment.

Metals in sediments are also indicative of the level of metal exposure of benthic animals in contact with bottom sediments and suspended particulate materials. However, the route through which organisms assimilate bioavailable sediment-bound metal is not well understood. In order to better estimate bioavailable metal exposures, the tissues of the organisms themselves may be analyzed for trace metals. Benthic organisms concentrate most metals to levels higher than those that occur in solution, and therefore, the record of tissue metal concentrations can be a more sensitive indicator of anthropogenic metal inputs than the sediment record. Different species concentrate metals to different degrees. If one species is analyzed consistently, the results can be employed to indicate trace element exposures to the local food web. For example, silver (Ag), copper (Cu) and selenium (Se) contamination, originally observed in clams (*Macoma balthica*) at the Palo Alto mudflat, was later found in diving ducks, snails, and mussels also from that region (Luoma *et al.*, USGS, unpublished data).

Because of the proven value of the above approaches for monitoring near field receiving waters, the California Regional Water Quality Control Board (RWQCB) has described a Self Monitoring Program, with its re-issuance of the National Pollutant Discharge Elimination System (NPDES) permits for South San Francisco Bay dischargers, that includes specific receiving water monitoring requirements. The RWQCB requires inshore monitoring of metals and other specified parameters using the clam *M. balthica* and fine-grained sediments. The monitoring protocols should be compatible with or complement the Board's Regional Monitoring Program. Monitoring efforts are to be coordinated with the 24 years of previous data collected by the U. S. Geological Survey (USGS) from the site south of the Palo Alto discharge site.

Objectives

The purpose of this study is to present trace metal concentrations observed in sediments and clams at an inshore location in South San Francisco Bay. These data and those collected in earlier studies (Luoma *et al.*, 1991; 1992; 1993; 1995; 1996; 1997; 1998; Wellise *et al.*, 1999; David *et al.*, 2002; Moon et. al. 2003) will be used to meet the following objectives:

- Provide data to assess seasonal and year-to-year trends in trace element concentrations in sediments and clams in receiving waters near the Palo Alto Regional Water Quality Control Plant (PARWQCP) as designated in the RWQCB's Self-Monitoring Program guidelines.
- Present the data within the context of historical changes inshore in South San Francisco Bay and within the context of other locations in San Francisco Bay published in the international literature.
- Coordinate inshore receiving water monitoring programs for PARWQCB and provide data compatible with relevant aspects of the Regional Monitoring Program. The near field data will augment the Regional Monitoring Program as suggested by the RWQCB.
- Provide data, that could support other South San Francisco Bay issues or programs such as development of sediment quality standards.

Study Site

The Palo Alto site (PA) is located one kilometer south of the intertidal discharge point of the PARWQCP (Figure 1). Spatial distributions of metal concentrations near the PARWQCP site were described by Thomson *et al.* (1984) (also reported by Luoma *et al.*, 1991; 1992; 1993; 1995; 1996; 1997; 1998; Wellise *et al.*, 1999; David *et al.*, 2002; Moon et. al. 2003). The PARWQCP appeared to be the primary source of the elevated metal concentrations at the PA site in the spring of 1980, based upon spatial and temporal trends of Cu, Ag and zinc (Zn) in clams and sediments (Thomson *et al.*, 1984; Cain and Luoma, 1990). Metal concentrations in sediments and clams (*M. balthica*), especially Cu and Ag, have declined substantially since the original studies as more efficient treatment processes and source control were employed that significantly reduced metal discharges from the treatment plant (Hornberger *et al.*, 2000). However, frequent sampling within a year was necessary to characterize those trends since there was significant seasonal variability (Cain and Luoma, 1990; Luoma *et al.*, 1985). This report characterizes data for the year 2003, employing the methods described in the succeeding section.

Previous reports (Luoma *et al.*, 1995; 1996; 1997; 1998; Wellise *et al.*, 1999) included a study area in addition to the Palo Alto sampling site. This area was located in a region that was influenced by discharge from the San Jose/Santa Clara Water Pollution Control Plant (SJ). Samples were collected from this site from 1994 to September 1999. Used as a reference, the SJ site allowed differentiation of local and regional long-term metal trends.

Methods

The PA site samples were collected from the exposed mudflat at low tide, with hand and shovel between January and December 2003 on a monthly basis. Sample were not collected during the months of July, August and November. Samples collected in the field included surface water, sediment, and the deposit-feeding clam *M. balthica*.

Sediment

Sediment samples were scraped from the oxidized surface layers (1-2 cm) of mud. These surface layers represent recently deposited sediments, or sediments affected by recent chemical reaction with the water column. Sediment samples were immediately taken to the laboratory and sieved through a 100 mm polyethylene mesh with distilled water to remove large grains that might bias interpretation of concentrations. The mesh size was chosen to match the largest grains typically found in the digestive tract of *M. balthica*. All sediment data reported herein were determined from the fraction that passed through the sieve (< 100 mm), termed silt/clay fraction. Previous studies have shown little difference between metal concentrations in sieved and unsieved sediments when silt/clay type sediment dominates at a site. However, where sand-size particles dominate the bed sediment, differences can be substantial. Sediments in extreme South San Francisco Bay can vary spatially and temporally in their sand content (Luoma *et al.*, 1995; 1996; 1997; 1998; Wellise *et al.*, 1999; David *et al.*, 2002; Moon *et al.*, 2003; also see SFEI, 1997). Where sand content varies, sieving reduces the likelihood that differences in metal concentration are the result of sampling sediments of different character. Some differences between the USGS and the Regional Monitoring Program results (SFEI, 1997) reflected the bias of particle size on the latter's data.

To provide a measure of bulk sediment characteristics at a site, and thus provide some comparability with bulk sediment determination such as those employed in the Regional Monitoring Program – San Francisco Estuary Institute (SFEI, 1997), the fraction of the sediment that did not pass through the sieve was determined. This fraction is termed silt/clay fraction. The bulk sediment was assessed to contain a percent sand (>100um) and a percent silt/clay (<100um) (Appendix A).

The fraction of sediment that did not pass through the sieve was weighed and the percentage of the bulk sample was determined to assess percent sand and percent silt/clay in the sediment (Appendix A). The <100 mm fraction was dried at 60º C, weighed, and then measured into 0.4 to 0.6 gram aliquots in replicates for analysis. The samples were again dried at 60º C before re-weighing and extraction. The replicate sub samples were digested for near-total metal analysis by refluxing in 10 ml of concentrated nitric acid until the digest was clear. This method is comparable with the recommended procedures of the US Environmental Protection Agency and with the procedures employed in the Regional Monitoring Program. It also provides data comparable to the historical data available on San Francisco Bay sediments. While near-total analysis does not result in 100% recovery of all metals, recent comparisons between this method

and more rigorous complete decomposition show that trends in the two types of data are very similar (Hornberger *et al.*, 1999). After decomposition, samples were evaporated until dry and reconstituted in dilute hydrochloric acid for analysis. The hydrochloric acid matrix was specifically chosen because it mobilizes silver (Ag) into solution through the creation of Ag-chloro complexes. Sediment samples were also subjected to a partial weak acid extraction in 0.6 N Hydrochloric acid (HCl), as a crude chemical estimate of bioavailable metal. These sub samples were extracted for 2 hours with 12 ml of acid at room temperature. The extract was pressure filtered through a 0.45 mm membrane filter before analysis. Percent organic carbon, percent organic nitrogen, d13C, d15N were determined using a continuous flow isotope ratio mass spectrometer (IRMS) (Appendix A). Prior to analysis, samples were acidified with concentrated HCl vapor to remove inorganic carbon.

Clams

More than 60 individuals of *M. balthica* were collected on each sampling occasion. When possible, the range of sizes (shell length) was maximized by intensive field sampling. Salinity was determined for surface water and the mantle water of clams at the time of collection using a refractometer. Mantle water and surface water salinity were typically within 1 ppt (‰) of each other. Only surface water values are reported. Clams were returned to the laboratory and held for 48 hours in ocean water diluted to the ambient salinity at the time of sampling to depurate undigested material from their digestive tracts. After depuration, individual clams were separated into 1 mm size classes, based on maximum shell length. Soft tissues from all of the individuals in a size class were collected to constitute a single sample for analysis. Samples for each date were thus composed of six to eight replicate composites, with each composite consisting of 2 to 19 clams of a similar shell length. Calm tissue samples were dried, weighed and refluxed in concentrated nitric acid until the digest was clear. Digests were then dried and reconstituted in dilute 0.6 N hydrochloric acid for trace metal analysis.

Metals Analysis

Metals analysis, aluminum (Al), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), nickle (Ni), silver (Ag), vanadium (V) and zinc (Zn), was conducted by using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) (Appendix B and C). Mercury (Hg) and Selenium (Se) were determined in both sediment and clam tissues by Hydride Atomic Absorption Spectrophotometry (Appendix D). Mercury subsamples were digested at 100º C in aqua regia, re-digested in 10 percent nitric acid plus potassium dichromate and then reduced at the time of the hydride analysis (Elrick and Horowitz, 1985).

All glassware and field collection apparatus used were acid washed, thoroughly rinsed in ultra-clean deionized water, dried in a dust-free positive pressure environment, sealed and stored in a dust free cabinet. Quality control was maintained by frequent analysis of blanks and analysis of National Institute of Standards and Technology (NIST) standard reference materials (tissues and sediments). Within each analytical run, analysis was calibrated using a two point calibration curve. Calibration was followed by quality control checks with prepared quality control standards before, during (approximately every 10 samples) and after each analytical run. A full QA/QC plan is available upon request. Analyses of NIST reference materials (oyster tissue, San Joaquin soils) were within the acceptable range of certified values reported by NIST or were consistent where the nitric acid digest did not completely decompose the sediment samples (Appendix E). For sediment and clam analysis, method limits of detection (LOD) and minimum levels of quantification (LOQ) were evaluated using the procedures outlined in EPA

2003 and Glasser *et. al.* 1981. To account for matrix effects, NIST SRM 2711 and NIST SRM 2976 were used (Appendix F). Very high recoveries for Cd have been observed for the sediment standard using the methods listed above. High recoveries are probably due to analytical concentrations near the detection limit for Cd combined with matrix effects. Therefore, Cd in the sediments for 2003 is not presented in this report. A figure with data collected prior to 2000 is given for reference (Appendix G).

Results and Discussion

Salinity

The weather in San Francisco Bay is characterized by a winter rainy season and a summer dry season (Figure 2). The amount of precipitation in 2003 was average, but much of this rain was concentrated in December of 2002. The rainy season of 2003 was preceded by four years of below average rainfall. None of these years showed months having rain events as large as that seen in December of 2002.

Surface water salinity values show a seasonal pattern governed by wet and dry seasons (Figure 3, Table 1). Salinities were low during the winter rainy season and salinities were high through the summer dry season. For 2003 salinities were generally high indicating relatively low runoff during the previous winter. Salinity did not go below 19 ppt during the winter of 2003, representing one of the highest wintertime salinities measured during this study.

Sediments

Percent silt/clay in sediments indicates particle size distributions before sediments were sieved. At Palo Alto, percent silt/clay, Al and Fe typically follow a seasonal cycle of increasing early in the year then declining to a minimum by September or October. For this site, Thompson-Becker *et al.* (1985) suggested that fine sediments, accompanied by high Al and Fe concentrations, are dominant during the period of freshwater input (low salinities through April), reflecting annual terrigenous sediment inputs from runoff. Coarser sediments dominated later in the year because the seasonal diurnal winds progressively winnow the fine sediments into suspension through the summer. This seasonal pattern was repeated in 2003. The percent silt/clay varied from 25 - 95% (Figure 4). Al and Fe concentrations changed directly with the proportion of clay-size (very fine) particles within the 100 mm fraction of the sediment after sieving (Figure 4, Table 1). In December 2002 and January 2003 there was a rapid increase in percent silt/clay, Al and Fe. This rapid increase suggests that the years of relatively dry conditions, followed by the abruptly heavy rains in December 2002, may have deposited fresh terrigenous material to the site. The total organic carbon content also shows an increase in January 2003. This may be an indicator of fresh input of carbon rich fine material to the site. Overall the sediments of 2003 had an average organic carbon content of 1.21% (Table 1).

The trace metals Cr, Ni and V in sediments show a seasonal cycle (Figure 5, Table 2). The pattern of seasonal change for these metals in 2003 was typical of earlier years, with the highest concentrations early in the year (winter maximum) and the lowest concentrations in September-November. The concentrations of Cr and V increased in December of 2002 through January of 2003. This increase resulted in the highest concentrations observed during this study. The rapid increase and elevated concentrations of these elements are further evidence of input of fresh material. These metals are strongly enriched in some geologic formations within the

watershed. In North San Francisco Bay, studies of sediment cores indicated that concentrations of these elements similar to that reported here were derived from natural geologic inputs (Hornberger *et al.*, 1999). However, Cr and Ni also occur in the effluents of the PARWQCP. The seasonal variability and the similarities among Cr, Ni and V continue to suggest that hydrogeologic processes were the predominant influence on concentrations of these elements.

Copper exhibits a seasonal cycling signature (Figure 6, Table 2). Seasonal minima concentrations of near-total Cu in 2003 dropped below the effects range-low (ERL) guidelines set by the National Oceanic and Atmospheric Administration (Long *et al.*, 1995). This drop resulted in the lowest near-total Cu concentration observed to date. Long *et al.* (1995) defined values between ERL (Effects Range-Low) and ERM (Effects Range-Median) as concentrations that are occasionally associated with adverse effects (21 - 47% of the time for different metals). Values greater than the ERM were frequently associated with adverse effects (42% - 93% of the time for different metals). It must be remembered, however, that these effects levels were derived mostly from bioassay data and are not accurate estimates of sediment toxicity. Over the study period, near-total and partial-extractable Cu concentrations are tightly coupled with the exception of 2002. However, the continued decrease in near-total Cu in sediments was not completely reflected in the partial-extractable fraction (Figure 6). In 2003, the wintertime maximum was the highest observed since 1997. The summertime minimum concentration of 2003 was comparable to the record lows observed during the last two years.

Zinc concentrations reversed their previous decreasing trend (Figure 7). In 2003, the winter maximum for total extractable Zn, rose above the ERL for the first time in five years. The record for partial-extractable Zn also showed this increase. The winter maximum was the highest observed since 1996 and the summer minimum was the highest observed since 1999. The increase in concentration coincided with the precipitation event of December 2002.

Concentrations of partial-extractable Ag in sediments were observed to increase over previous years and were some of the highest values recorded during this study (Figure 8, Table 2). The winter maximum was the highest observed since this study began in 1994. Similarly the summer minimum was the highest observed since the summer of 1994. The winter peak was coincident with the large amount of precipitation observed in December 2002. Even though these values were elevated, partial-extractable Ag maintained the range of concentration that was perceived to be attributable to seasonal cycling of the element (Figure 8, Table 2). This range was above the established concentration for uncontaminated sediments in San Francisco Bay (Hornberger *et al.*, 1999) but well below the Ag ERL.

Mercury concentrations in Palo Alto sediment remained consistent with earlier years at an enrichment level typical of San Francisco Bay as a whole (0.2 - 0.4 µg/g) (Figure 9, Table 2).

Concentrations of Se in sediments showed a maximum in February 1999 that was more elevated than the corresponding seasonal maxima in previous years (Figure 9, Table 2). This maximum was followed by relatively low concentrations in 2000, 2001 and 2002. In 2003 there was a slight increase in maximum Se concentration over the previous two years. This peak is still relatively low compared with the maximum of 1999, which was comparable to the highest concentrations observed in sediments anywhere in the San Francisco Bay (Hornberger *et al.*, 1999).

Clams

Exposures to Cu and Ag at Palo Alto, as reflected in clam tissues, have been of special interest due to the high concentrations observed in the 1970s and 1980s (Figures 10&11, Tables 3&4, respectively). Exposures to both metals were lower throughout the 1990s than in the years prior to 1988. Minimum concentrations in clam tissues were observed in 1991, but a five-year period of slightly increased concentrations followed. Concentrations declined in 1997 and have remained relatively constant through 2003.

Intra-annual variations in Cu concentrations in clam soft tissues display a consistent seasonal signal, with fall/winter maxima and spring/summer minima (Figure 12). The winter maxima and the amplitude of the seasonal cycle were greater between 1994 and 1997 than in subsequent years. Ag also displayed the same long-term seasonal pattern as Cu (Figure 13). These trends most likely reflect the interaction of the changing exposure regime of the site with the annual growth cycle of *M. balthica* (Cain and Luoma, 1990).

Seasonal cycles were also exhibited in Cr (Figure 14, Table 2), Ni (Figure 15, Table 2) and Zn (Figure 16, Table 2). Wellise *et al.* (1999) observed that the trends of these metals in Palo Alto clam samples were similar to those from the San Jose site, suggesting that regional-scale processes may be more important than treatment plant inputs in controlling seasonality and bioavailability of these elements. The seasonal signal continued in 2003 wherein the highest Cr, Ni, and Zn concentrations were observed during winter (December-March) and the minima typically occurred during summer (June-September). In 2003, both Cr and Ni showed an increase in winter-maximum tissue concentration. These were the highest concentrations observed in seven and six years, respectively. The winter maximum for Zn showed a slight increase over the previous two years. However, despite this slight increase, there appears to still be a general decreasing trend in winter maxima concentrations since 1996.

In 1996, there was a decrease in mercury concentrations (Figure 17). Since 1996, lower levels of Hg have persisted. In 2003, Hg concentrations continued to be lower than the pre-1996 decrease (Figure 17). The minimum concentration observed in April of 2003 was the lowest concentration observed during this study.

Selenium concentrations in clam tissue and sediments showed similar trends (Figure 18). The average sediment concentrations in 2001 and 2002 were lower than previous years. In 2003, concentrations continued to remain low except for the in January 2003. The winter maximum in 2003 was the second highest concentration of Se in clam tissue observed during this study.

Condition index (CI) is a measure of physiological "fatness", the tissue weight of a clam for a given length. It is an index of the clams' well-being and is linked to the seasonal reproductive cycle. Seasonally, a clam of a given shell length will increase in weight as a part of growth and during the early stages of reproduction. This weight is then lost during and after reproduction. Other stressors such as pollutant exposure, salinity extremes or lack of food can also reduce condition index.

The condition index for 2003 was greater than any previous years (Figure 19). Moreover, the annual minimum for 2003 was also the highest in the 16-year dataset. This may be suggestive of further improvement in clam health, however, further investigation is necessary to understand the dynamics of food availability and condition to interpret this observation. A simple correlation between maximum condition index and the preceding months' maximum metal exposure was not significant (Figure 20). Still, the data distribution raised the possibility that Cu concentrations above 80 - 90 µg/g might affect growth in the bivalves.

Conclusion

Frequent sampling is essential for characterizing ambient metal concentrations in the environments in the vicinity of the outfall. Monitoring studies can not always unambiguously determine the causes of the trends in metals concentrations in either sediments or clams. The value of monitoring was to describe trends, identify previously undocumented phenomena, and raise otherwise unrecognized hypotheses that might guide detailed explanatory studies. The interpretation of time series data allows the separation of signals from anthropogenic sources and natural annual and inter annual variability. For many elements of regulatory interest, including Cr, V, Ni, and Zn, regional scale factors appeared to influence sedimentary and bioavailable concentrations, although this may not be completely accurate in all years. The decrease in Cu and Ag concentrations in clam and sediment samples reflected the continued decrease in the loading of these metals from the treatment plant. Other variables such as precipitation that may influence the seasonal and year to year patterns in sedimentary and tissue concentrations should still be investigated.

References

Cain, D. J. and Luoma, S. N., 1990, Influence of seasonal growth, age and environmental exposure on Cu and Ag in a bivalve indicator, *Macoma balthica* in San Francisco Bay: Marine Ecology Progress Series 60, p. 45-55.

David, C. P. C., Luoma, S. N, Brown, C, Cain, D. J, Hornberger, M. and Lavigne, I. R. 2002. Near field receiving water monitoring of trace metals in clams (*Macoma balthica*) and sediments near the Palo Alto Water Quality Control Plant in South San Francisco Bay, California: 1999-2001. U. S. Geological Survey Open File Report 02-453. Menlo Park, California. 105pp.

Elrick, K. A. and Horowitz, A. J. 1985. Analysis of rocks and sediments for arsenic, antimony, and selenium, by wet digestion and hydride atomic absorption. U. S. Geological Survey Open File Report 85-497. Doraville, Georgia. 14pp.

Glaser, J.A., Foerst, D.L., Mckee, G.D., Quave, S.A., Budde, W.L. (1981) Trace analyses for wastewaters, Environ. Sci. Technol. Vol. 15, No. 12, pp 1426-1435.

Hornberger, M. I., Luoma, S. N., Van Geen, A., Fuller, C. C., and Anima, R. 1999, Historical trends of metals in the sediments of San Francisco Bay, California. Marine Chemistry 64, p. 39-55.

Hornberger, M.I., Luoma, S. N., Cain, D., Parchaso, F., Brown, C., Bouse, R., Wellise, C.J., Thompson, J., 2000, Bioaccumulation of metals by the bivalve *Macoma balthica* at a site in South San Francisco Bay between 1977 and 1997: Long-term trends and associated biological effects with changing pollutant loadings. U. S. Geological Survey Open File Report 99-55. Menlo Park, California.

Long, E. R., MacDonald, D. D., Smith, S. L., and Calder, F. D., 1995, Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments: Environmental Management, v. 19, p. 81-97.

Luoma, S. N., Cain, D. J., and Johansson, C., 1985, Temporal Fluctuations of Silver, Copper and Zinc in the Bivalve *Macoma balthica* at Five Stations in South San Francisco Bay: Hydrobiologia 129:109_120, 1985.

Luoma, S. N., Cain, D. J., Brown, C. and Axtmann, E. V., 1991, Trace Metals in Clams (*Macoma balthica*) and sediments at the Palo Alto Mudflat in South San Francisco Bay: April, 1990 - April, 1991. U. S. Geological Survey Open File Report 91-460. Menlo Park, California. 47pp.

Luoma, S. N., Cain, D. J., Brown, C. and Hornberger, M., 1992, Trace Metals in Clams (*Macoma balthica*) and sediments at the Palo Alto Mudflat in South San Francisco Bay: May 1991 - May 1992. U. S. Geological Survey Open File Report 92-456. Menlo Park, California. 51pp.

Luoma, S. N., Cain, D. J., Brown, C. and Hornberger, M., 1993, Trace Metals in Clams (*Macoma balthica*) and sediments at the Palo Alto Mudflat in South San Francisco Bay: June 1992 - June 1993. U. S. Geological Survey Open File Report 93-500. Menlo Park, California. 52pp.

Luoma, S. N., Cain, D. J., Brown, C. and Hornberger, M., 1995, Near Field Receiving Water Monitoring of Trace Metals in Clams (*Macoma balthica*) and sediments near the Palo Alto and San Jose/Sunnyvale Water Quality Control Plants in South San Francisco Bay: June 1993 - October 1994. U. S. Geological Survey Open File Report 95-299. Menlo Park, California. 83pp.

Luoma, S. N., Cain, D. J., Brown, C., Hornberger, M., and Bouse, R. 1996, Near Field Receiving Water Monitoring of Trace Metals in Clams (*Macoma balthica*) and sediments near the Palo Alto and San Jose/Sunnyvale Water Quality Control Plants in South San Francisco Bay: December 1994 - December 1995 U. S. Geological Survey Open File Report 96-203. Menlo Park, California. 90pp.

Luoma, S. N., Cain, D. J., Brown, C., Hornberger, M., and Bouse, R. 1997, Near Field Receiving Water Monitoring of Trace Metals in Clams (*Macoma balthica*) and sediments near the Palo Alto and San Jose/Sunnyvale Water Quality Control Plants in South San Francisco Bay: 1996 U. S. Geological Survey Open File Report 97-585. Menlo Park, California. 91pp.

Luoma, S. N., Wellise, C, Cain, D. J., Brown, C., Hornberger, M., and Bouse, R. 1998, Near Field Receiving Water Monitoring of Trace Metals in Clams (*Macoma balthica*) and sediments near the Palo Alto and San Jose/Sunnyvale Water Quality Control Plants in South San Francisco Bay: 1997 U. S. Geological Survey Open File Report 98-563. Menlo Park, California. 88pp.

Moon, E., David, C. P. C., Luoma, S. N, Cain, D. J, Hornberger, M. and Lavigne, I. R. 2003. Near field receiving water monitoring of trace metals in clams (*Macoma balthica*) and sediments near the Palo Alto Water Quality Control Plant in South San Francisco Bay, California: 2002. U. S. Geological Survey Open File Report 03-339. Menlo Park, California. 78pp.

San Francisco Estuary Inst. 1997, RMP, Regional Monitoring Program for Trace Substances: 1996. Richmond, CA. 349 pp.

Thomson, E. A., Luoma, S. N., Johansson, C. E., and Cain, D. J., 1984, Comparison of sediments and organisms in identifying sources of biologically available trace metal contamination: Water Research, v. 18, p. 755-765.

Thomson-Becker, E. A., and Luoma, S. N., 1985. Temporal fluctuations in grain size, organic materials and iron concentrations in intertidal surface sediment. Hydrobiologia, v. 129, p. 91-109.

U.S. Environmental Protection Agency Office of Water, 2003, Technical support document for the assessment of detection and quantification approaches, EPA-821-R-03-005, U.S.

Environmental Protection Agency, 1200 Pennsylvania Aveenue, NW Washington, DC 20460, pp 485.

van Geen, A and Luoma, S.N. 1999. A record of estuarine water contamination from the Cd content of foraminiferal tests in San Francisco Bay, California. Marine Chemistry 64, p. 57-69.

Wellise, C., Luoma, S. N., Cain, D. J., Brown, C., Hornberger, M., and Bouse, R. 1999, Near Field Receiving Water Monitoring of Trace Metals in Clams (Macoma balthica) and sediments near the Palo Alto and San Jose/Sunnyvale Water Quality Control Plants in South San Francisco Bay: 1998 U.S. Geological Survey Open File Report 99-455. Menlo Park, California. 101pp.

Figures

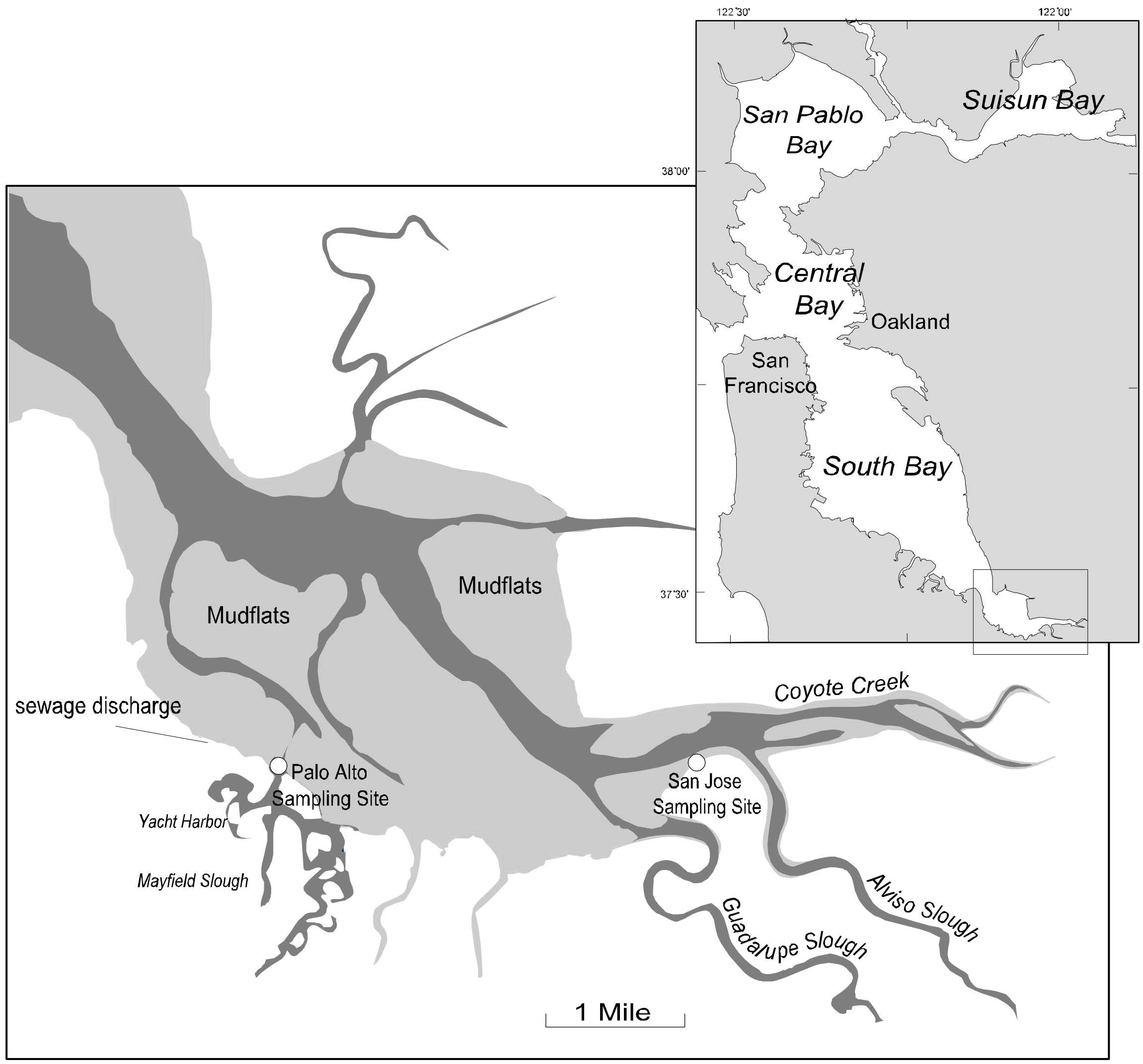


Figure 1. Location of the Palo Alto sampling station in South San Francisco Bay.

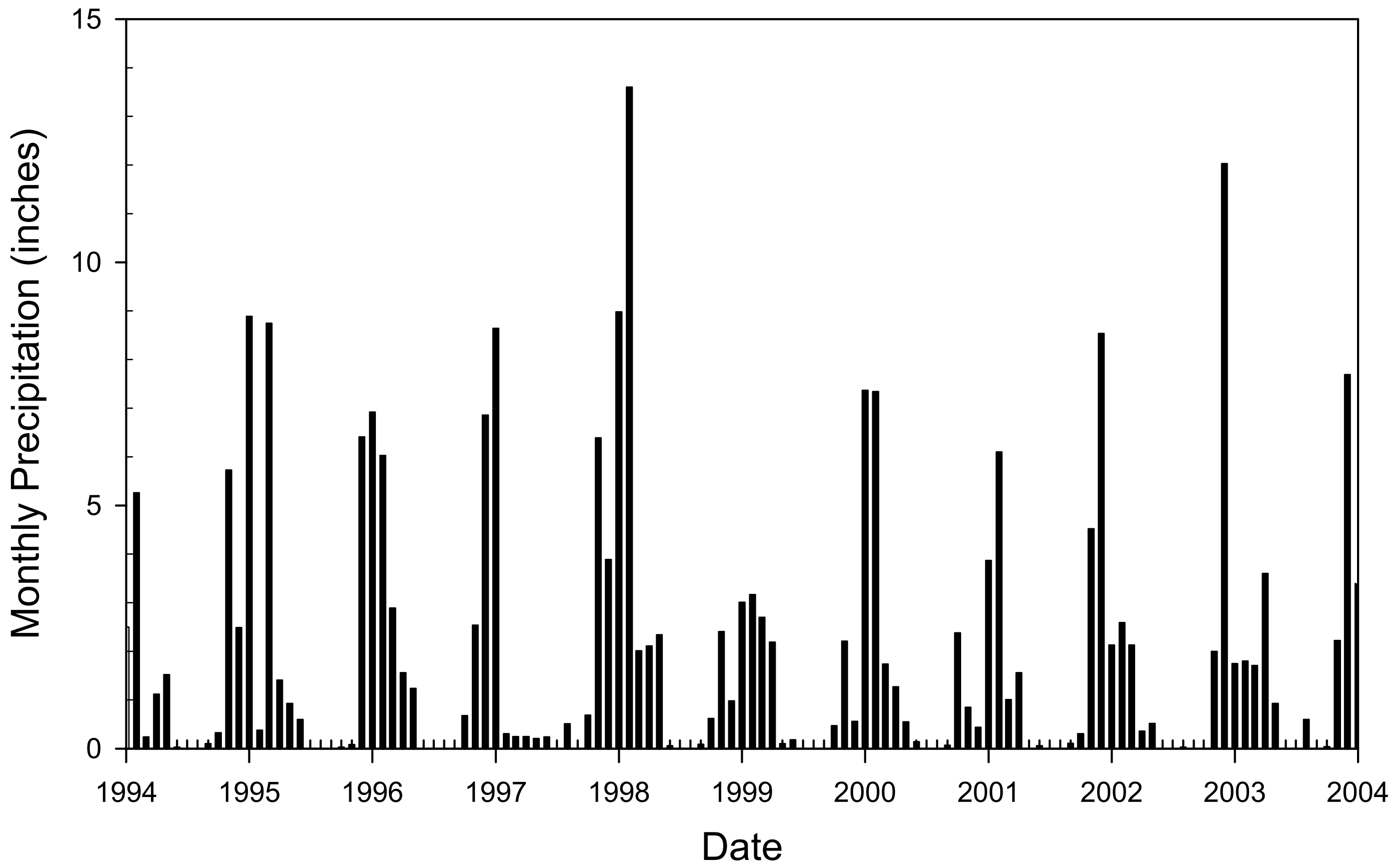


Figure 2. Precipitation at San Mateo gauge station (SFF)

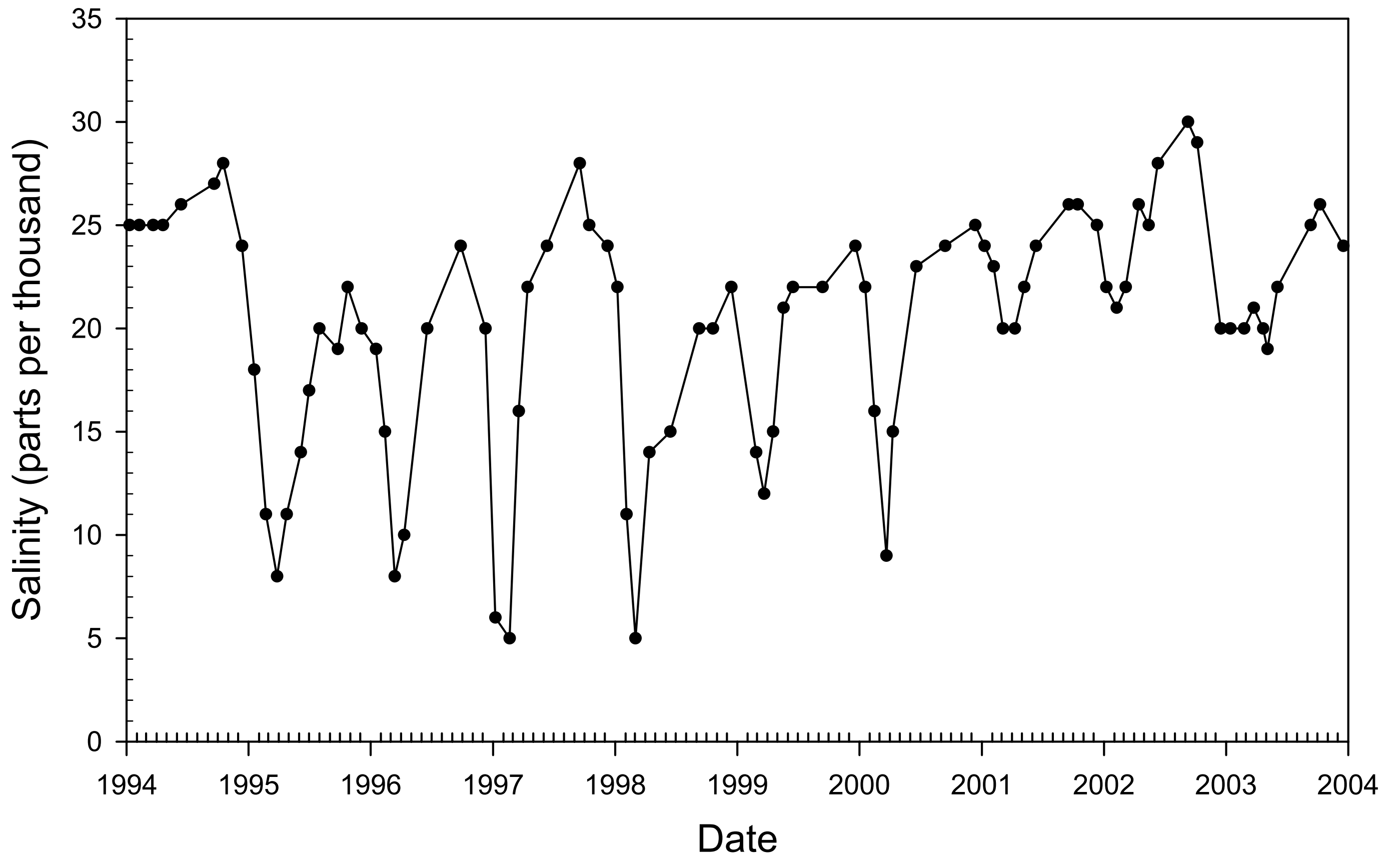


Figure 3. Water column salinity at Palo Alto from 1994 through 2003.

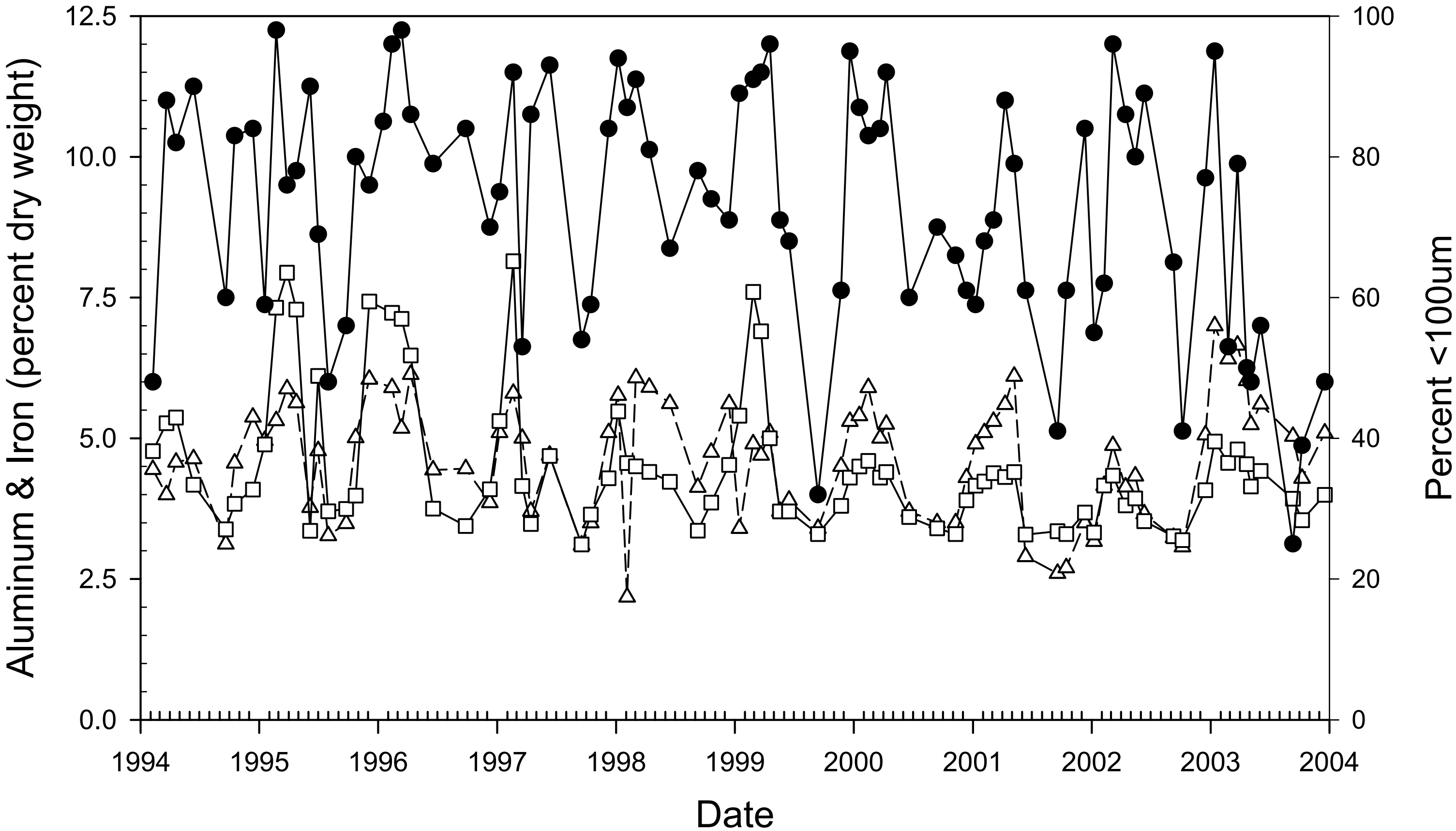


Figure 4. Percent aluminum (△), iron (□) and silt/clay (●) in sediments at Palo Alto from 1994 through 2003.

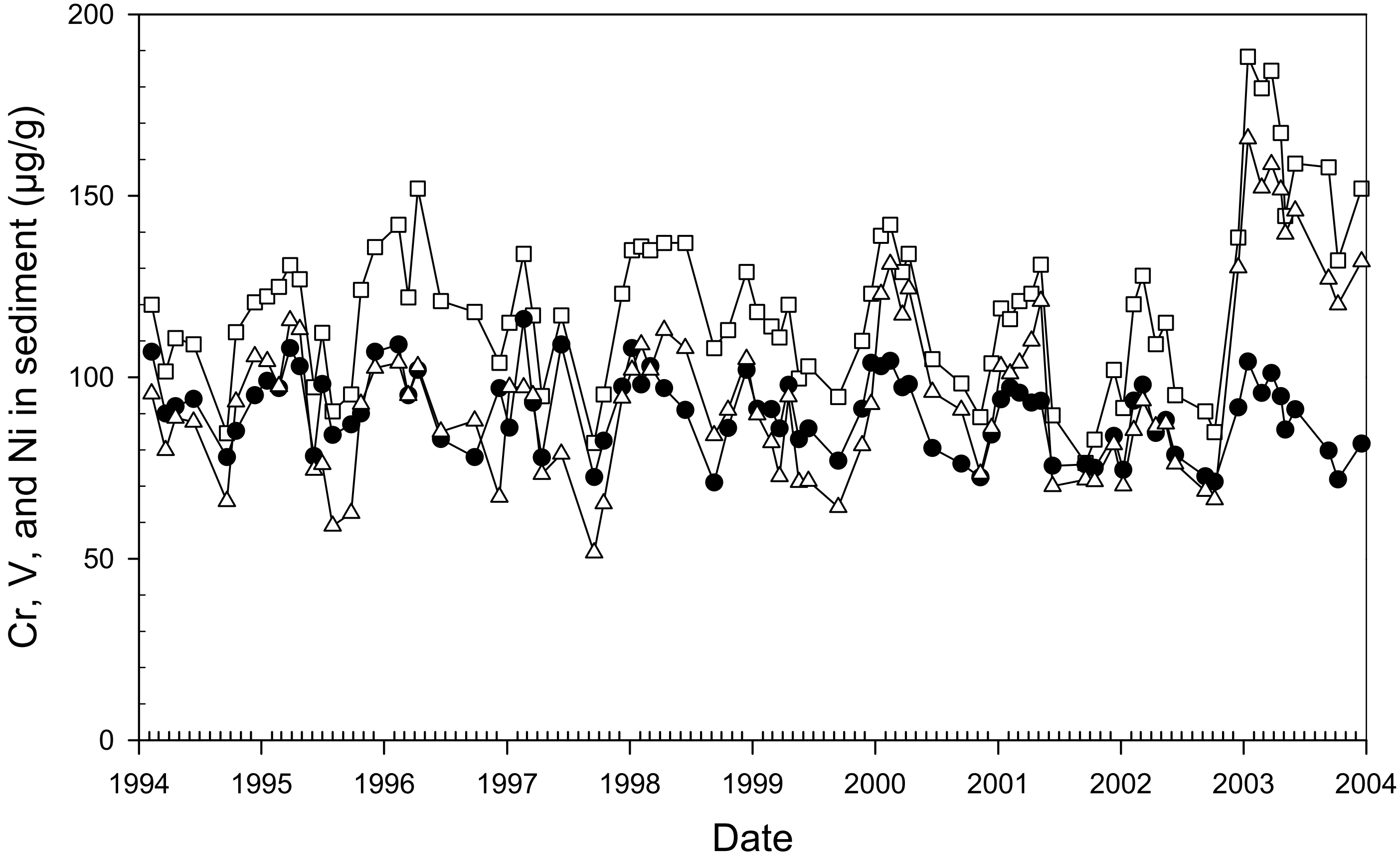


Figure 5. Near-total extraction concentrations of chromium (Cr) (□), nickel (Ni) (●) and vanadium (V) (△) in sediments at Palo Alto from 1994 through 2003.

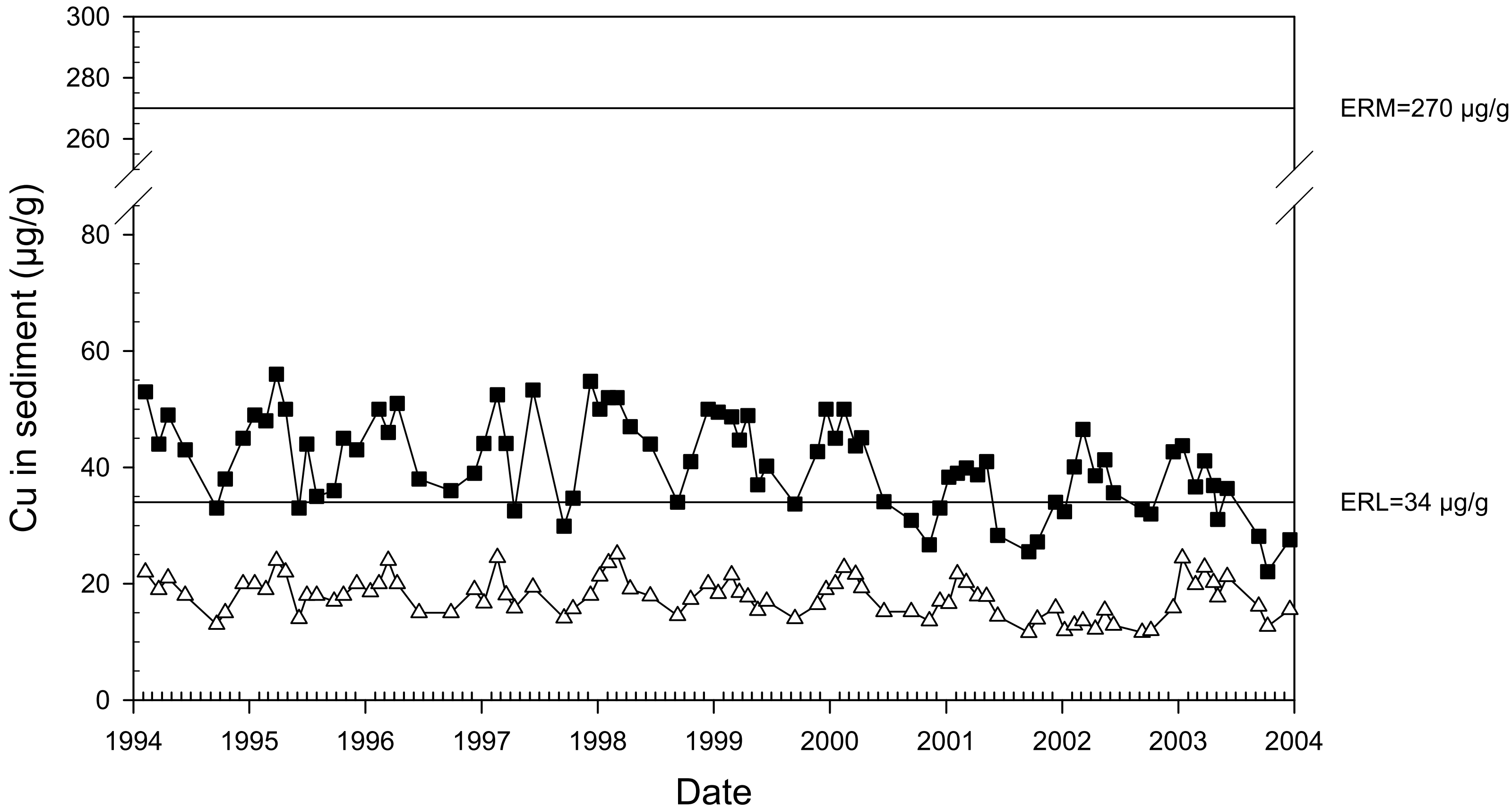


Figure 6. Near-total (■) and partial-extractable (△) copper concentrations in sediments at Palo Alto from 1994 through 2003.

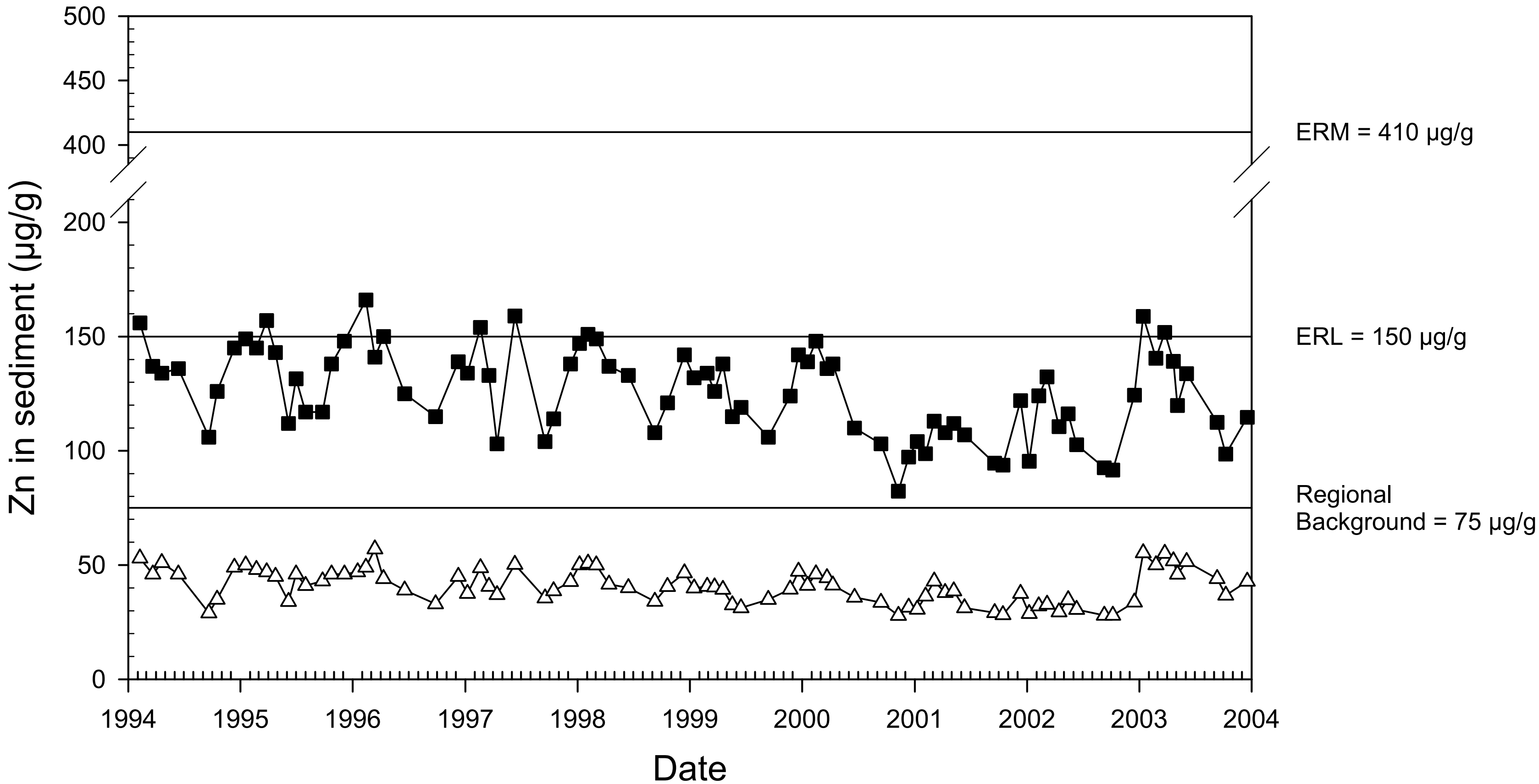


Figure 7. Near-total (■) and partial-extractable (△) zinc concentrations in sediments at Palo Alto from 1994 through 2003.

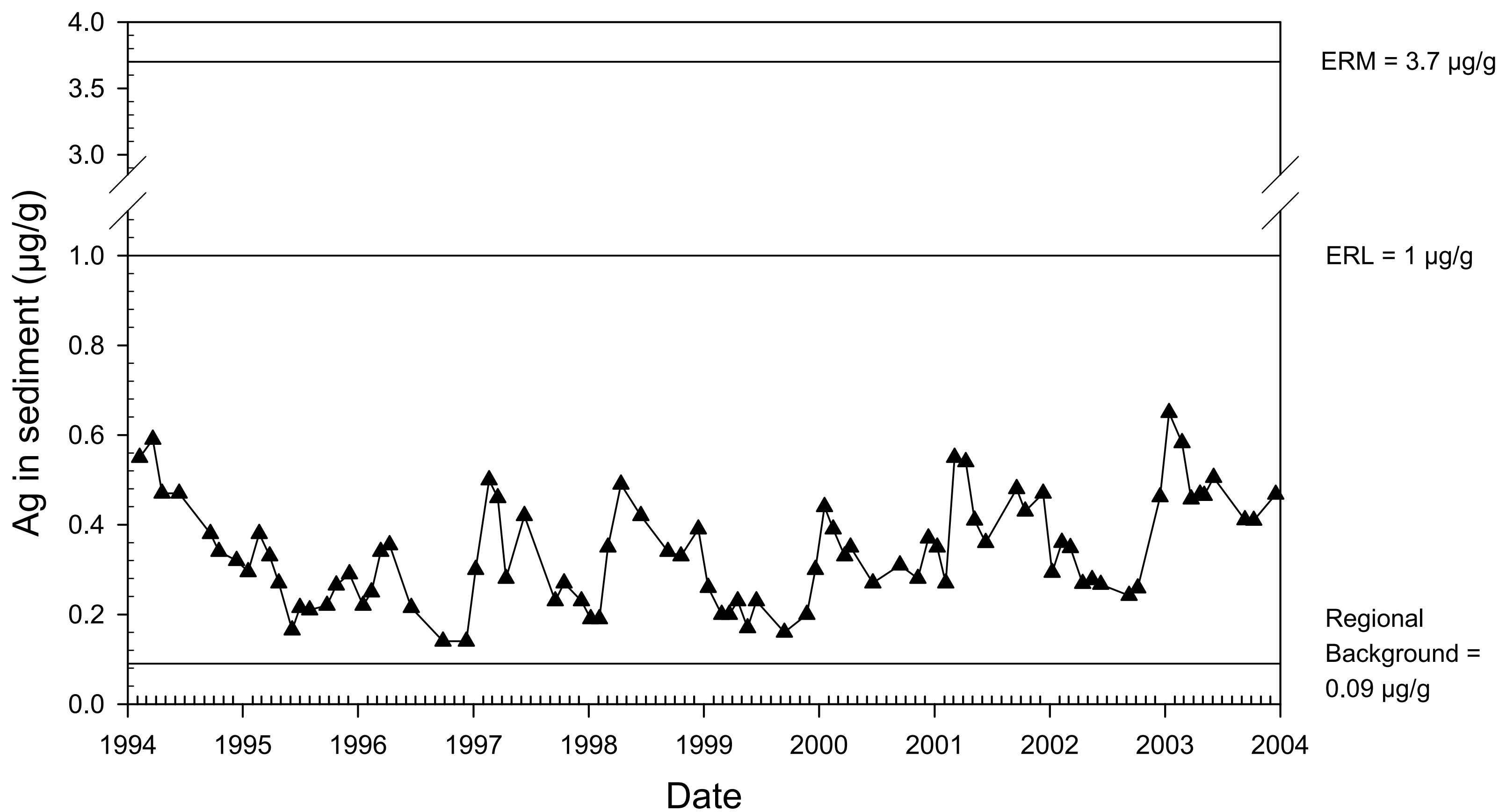


Figure 8. Acid-extractable silver concentrations in sediments at Palo Alto from 1994 through 2003.

Extractions were conducted with 0.6 N hydrochloric acid.

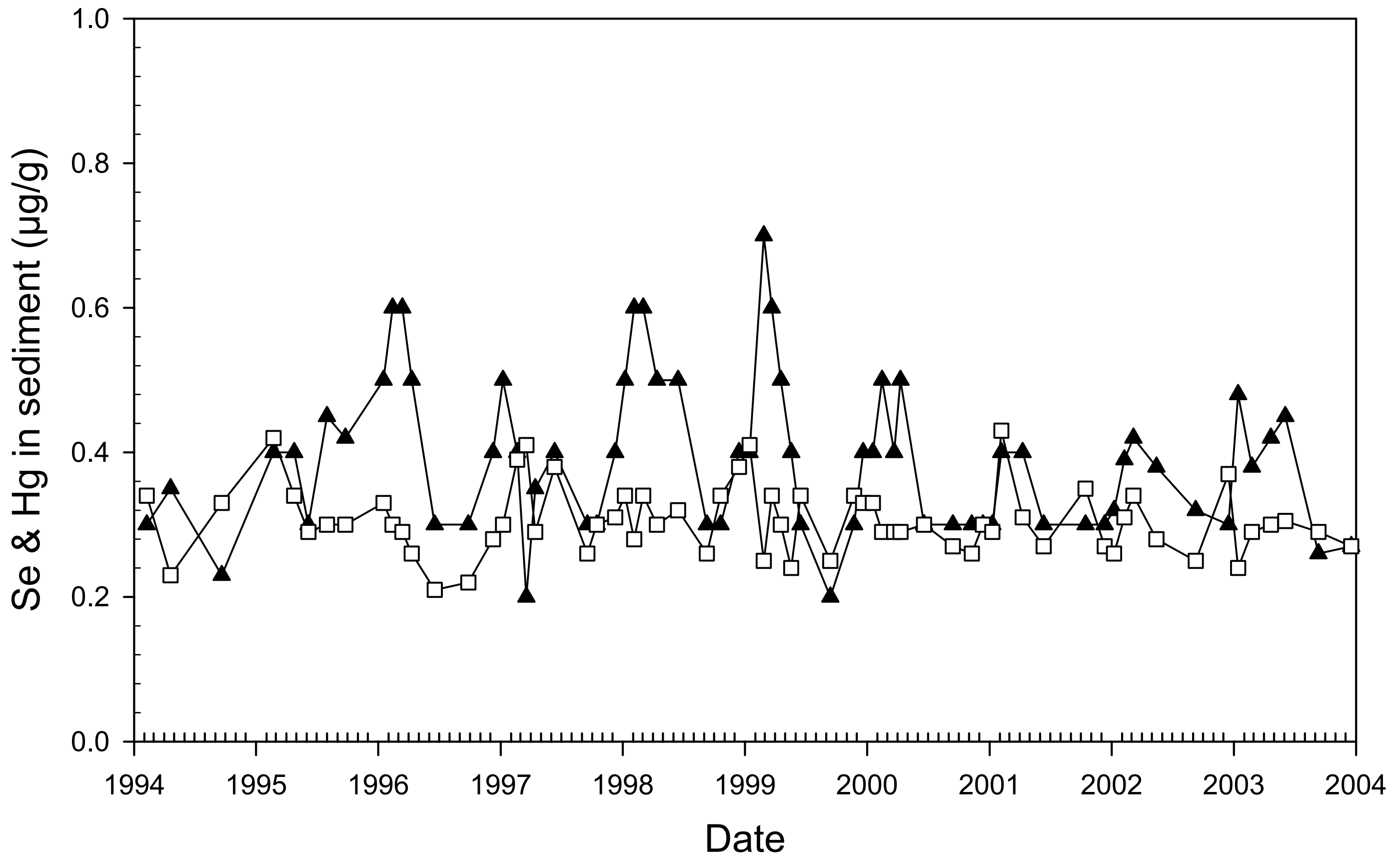


Figure 9. Concentrations of selenium (▲) and mercury (□) in sediments at Palo Alto from 1994 through 2003.

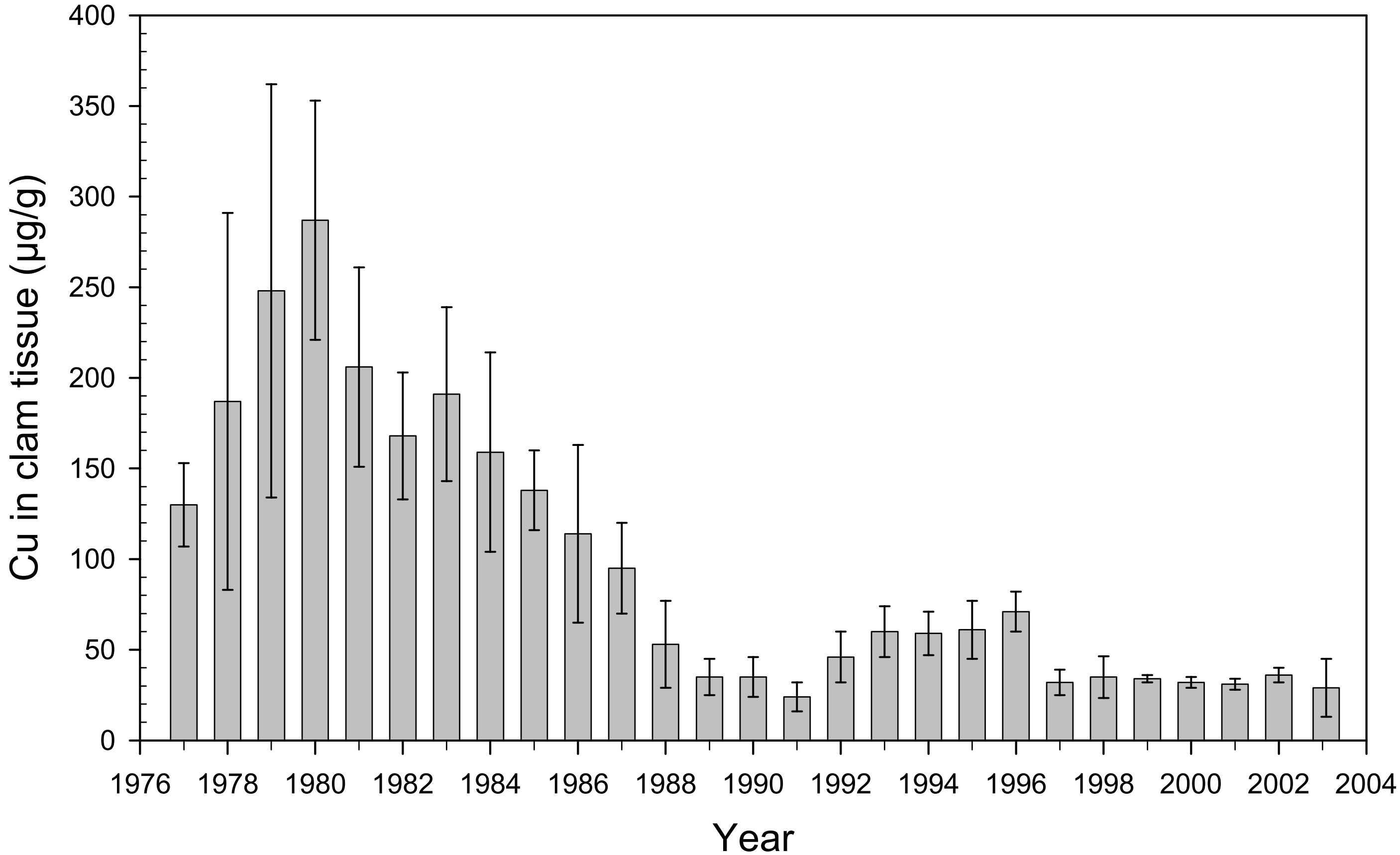


Figure 10. Annual mean concentrations of copper in *Macoma balthica* at Palo Alto from 1977 through 2003.
Error bars are the standard error of the mean (SEM).

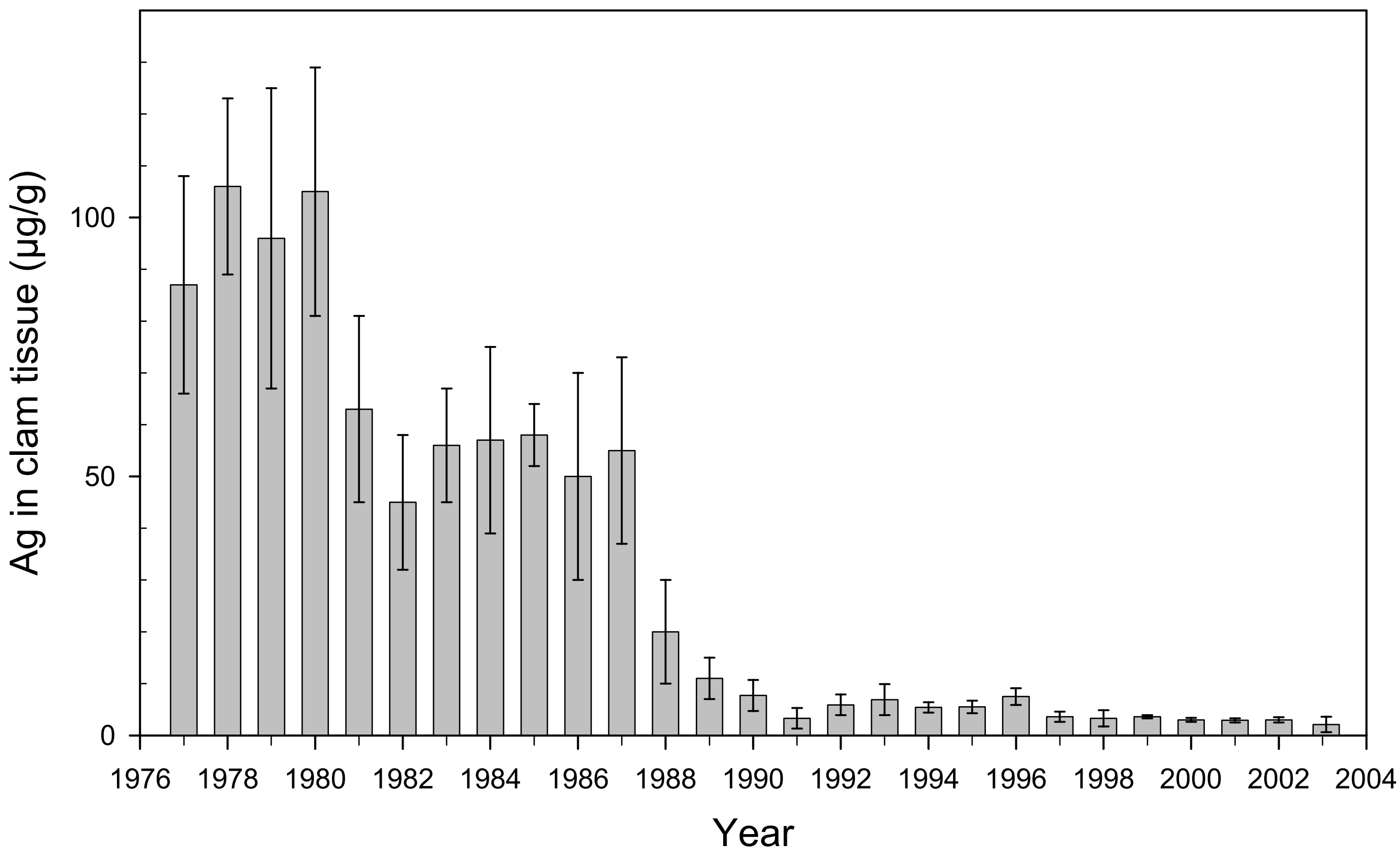


Figure 11. Annual mean concentrations of silver in *Macoma balthica* at Palo Alto from 1977 through 2003.
Error bars are the standard error of the mean (SEM).

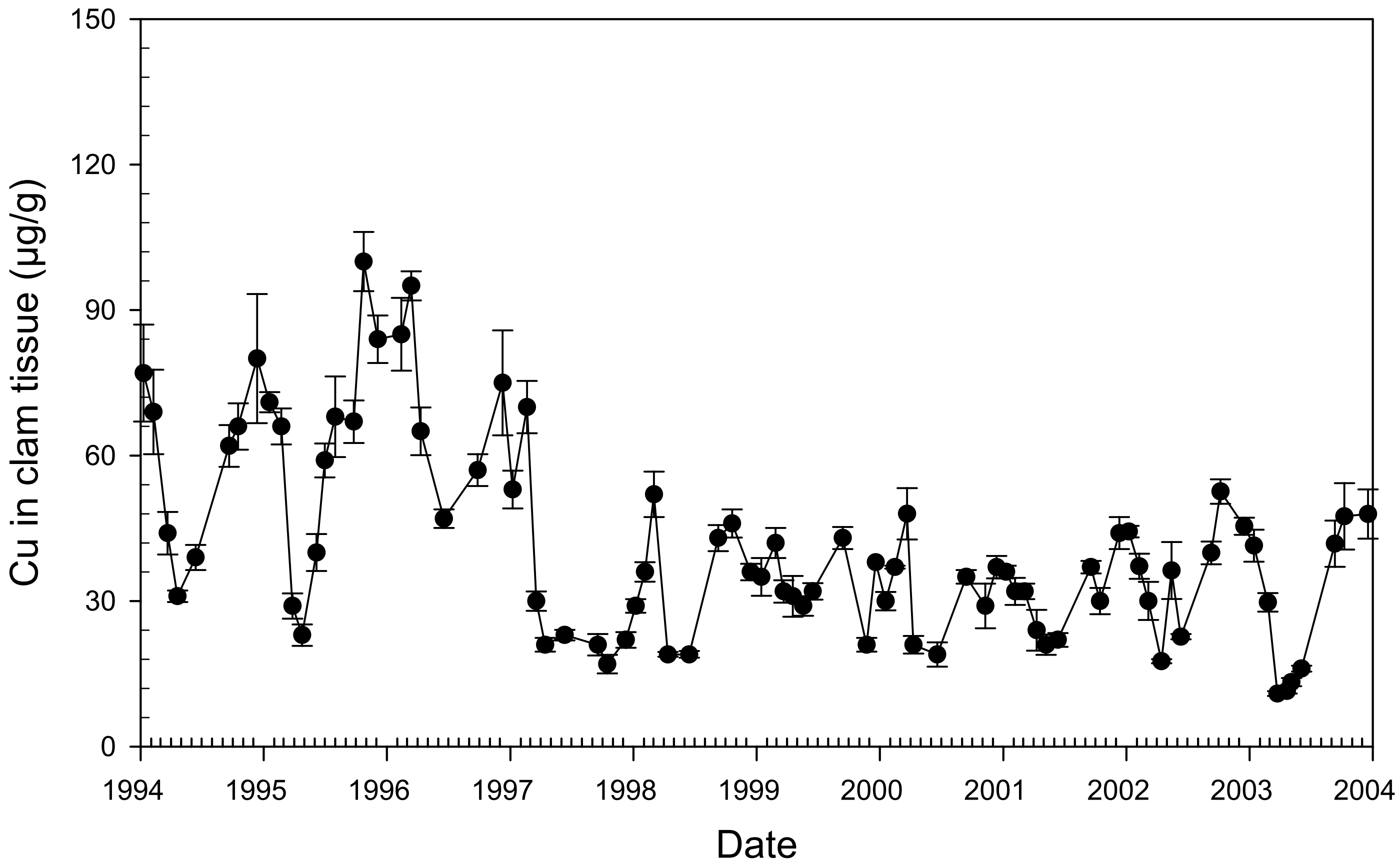


Figure 12. Concentrations of copper in *Macoma balthica* at Palo Alto from 1994 through 2003.

Error bars are the standard error of the mean (SEM).

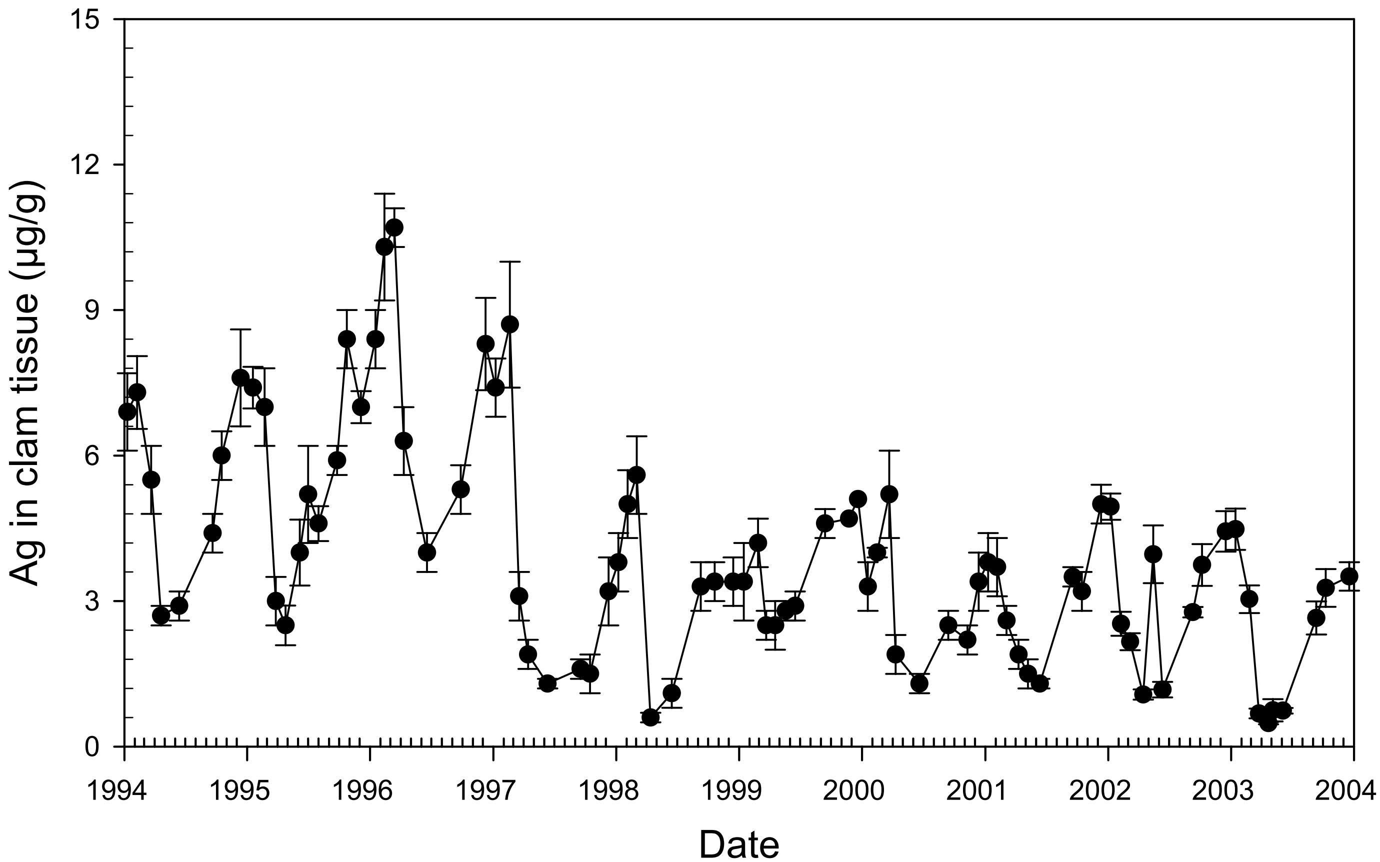


Figure 13. Concentrations of silver in *Macoma balthica* at Palo Alto from 1994 through 2003.

Error bars are the standard error of the mean (SEM).

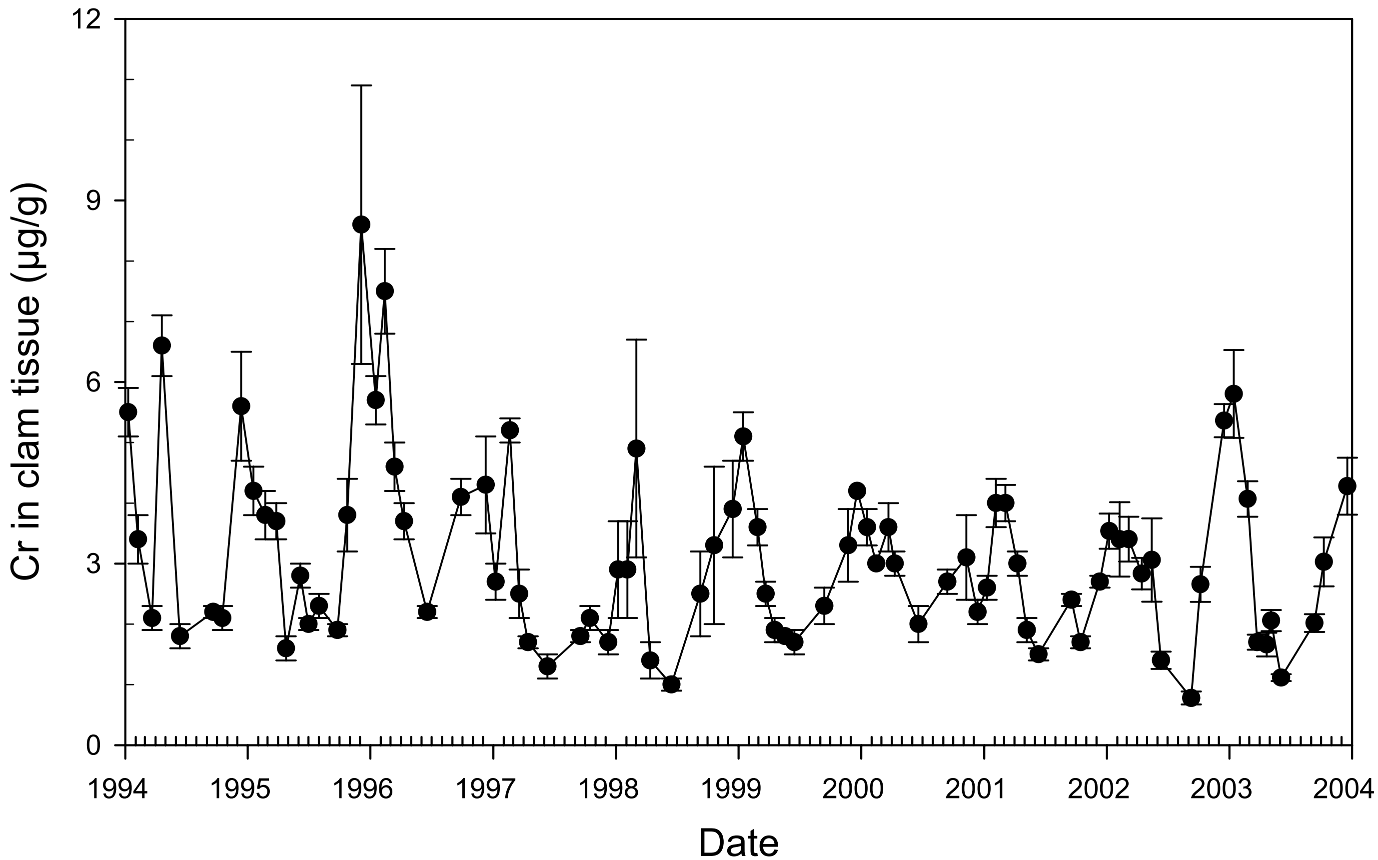


Figure 14. Concentrations of chromium in *Macoma balthica* at Palo Alto from 1994 through 2003.

Error bars are the standard error of the mean (SEM).

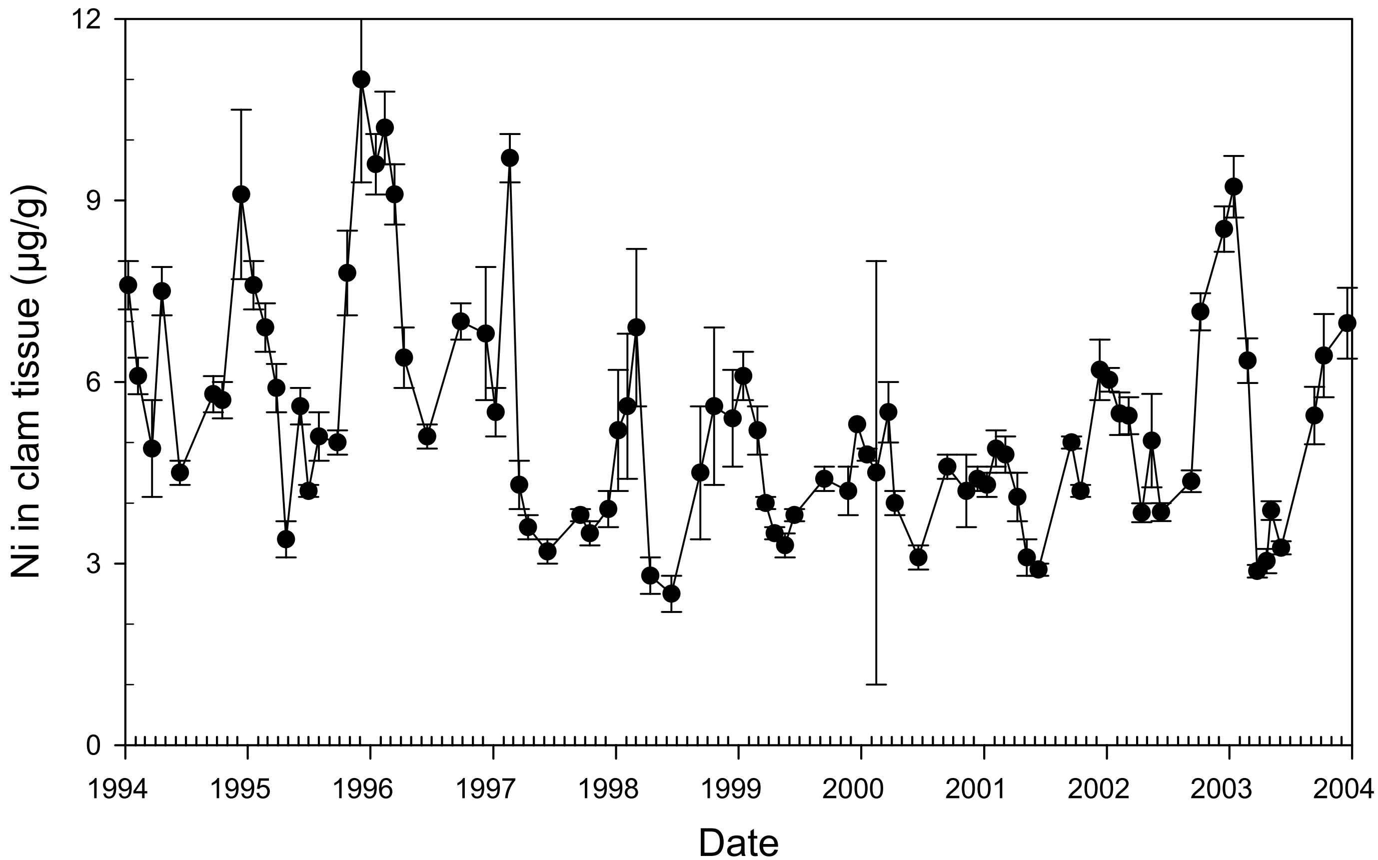


Figure 15. Concentrations of nickel in *Macoma balthica* at Palo Alto from 1994 through 2003.

Error bars are the standard error of the mean (SEM).

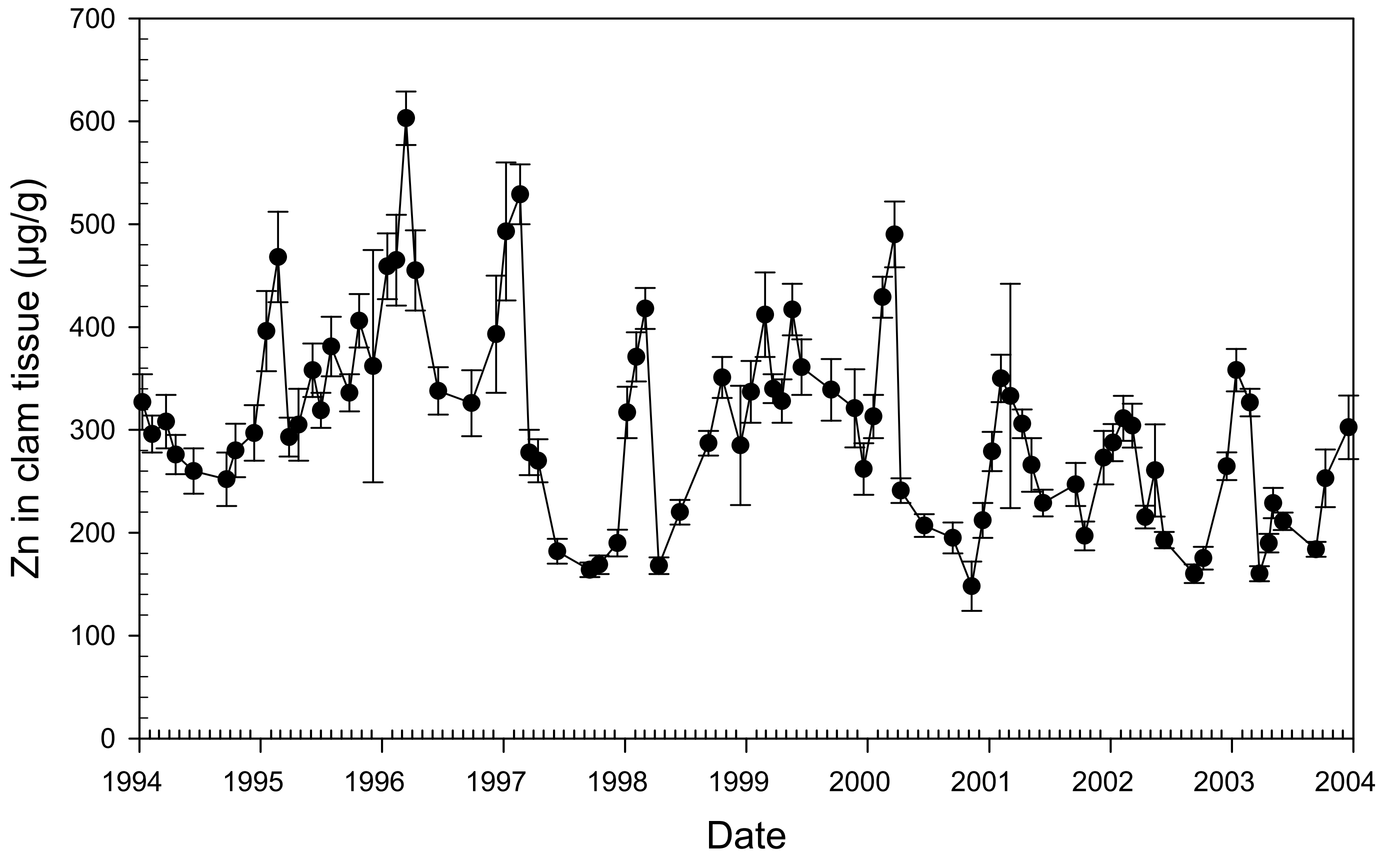


Figure 16. Concentrations of zinc in *Macoma balthica* at Palo Alto from 1994 through 2003.

Error bars are the standard error of the mean (SEM).

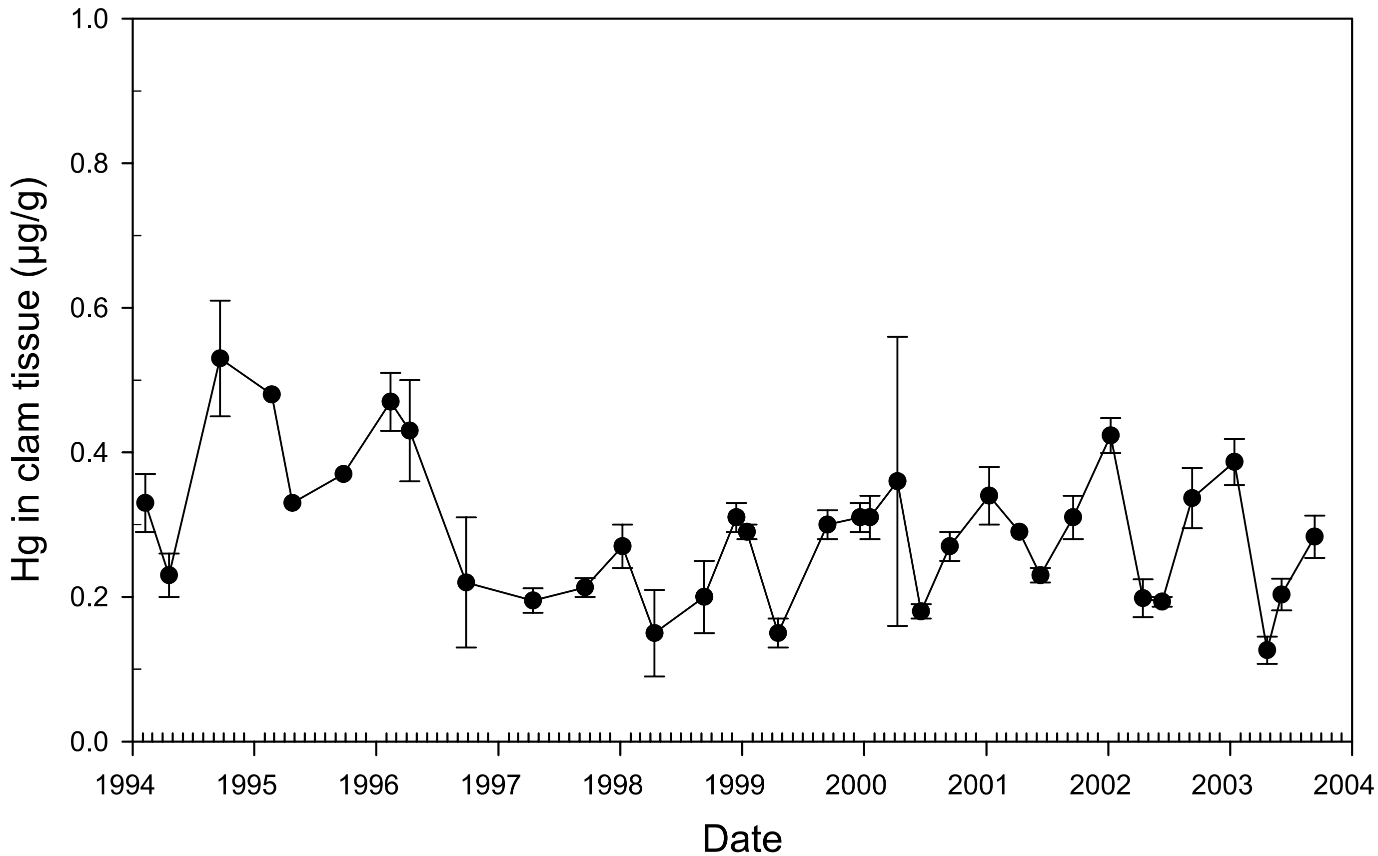


Figure 17. Concentrations of mercury in *Macoma balthica* at Palo Alto from 1994 through 2003.

Error bars are the standard error of the mean (SEM).

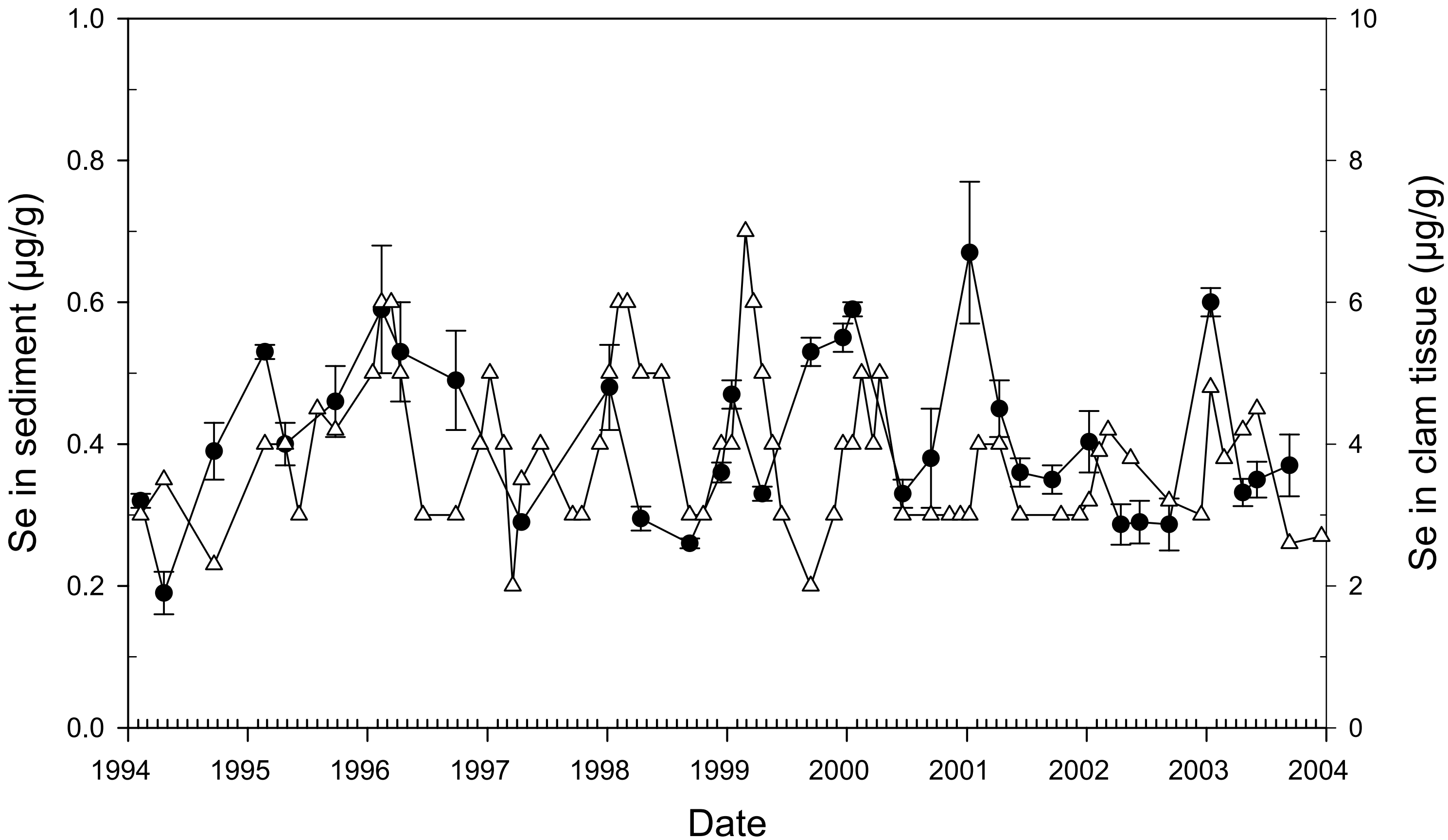


Figure 18. Concentrations of selenium in sediments (△) and in *Macoma balthica* (●) at Palo Alto from 1994 through 2003.
Error bars are the standard error of the mean (SEM).

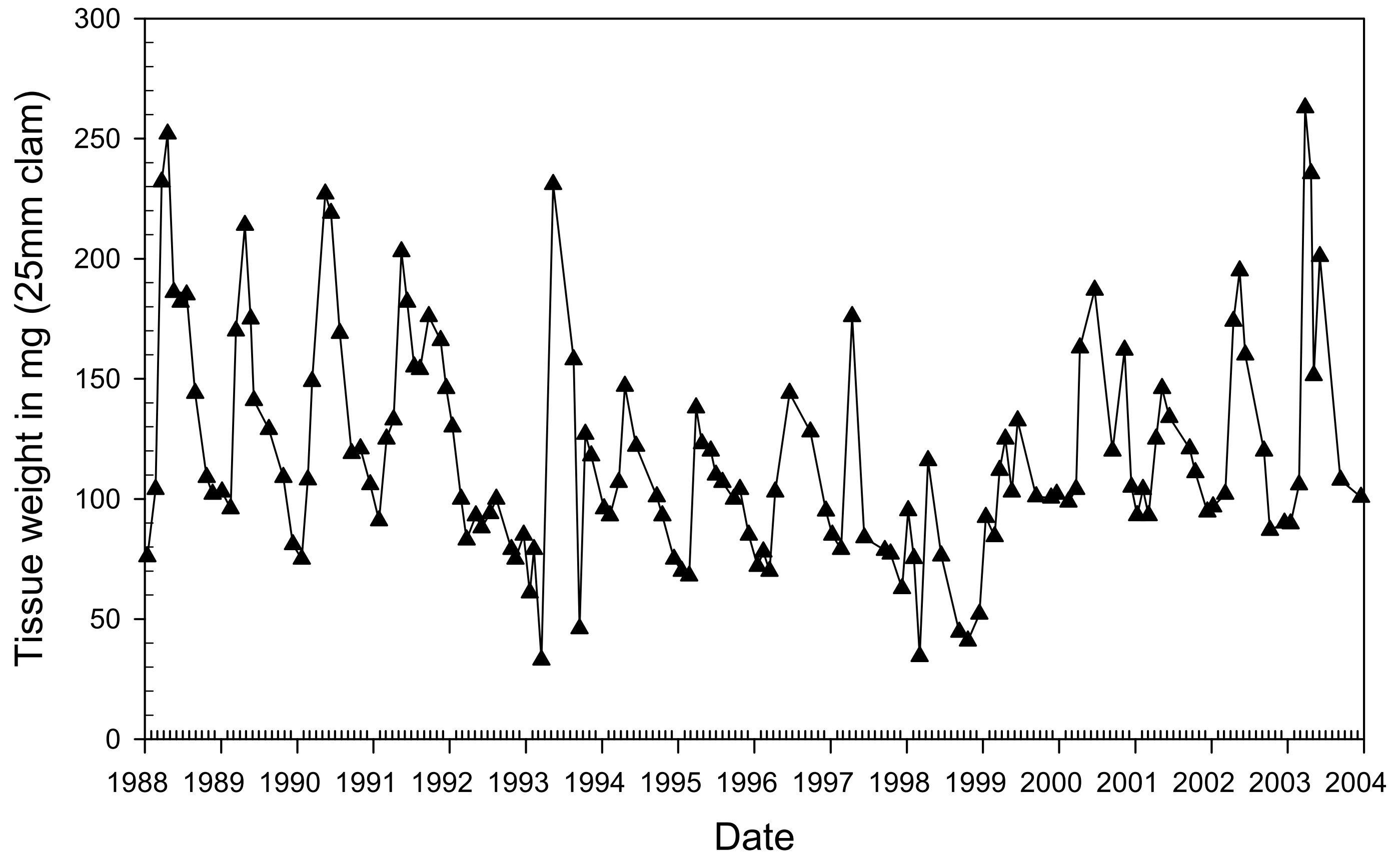


Figure 19. Condition index (CI) of *Macoma balthica* as determined between 1988 through 2003.

Condition index is defined as total weight of soft tissues of *Macoma balthica* having a shell length of 25 mm.

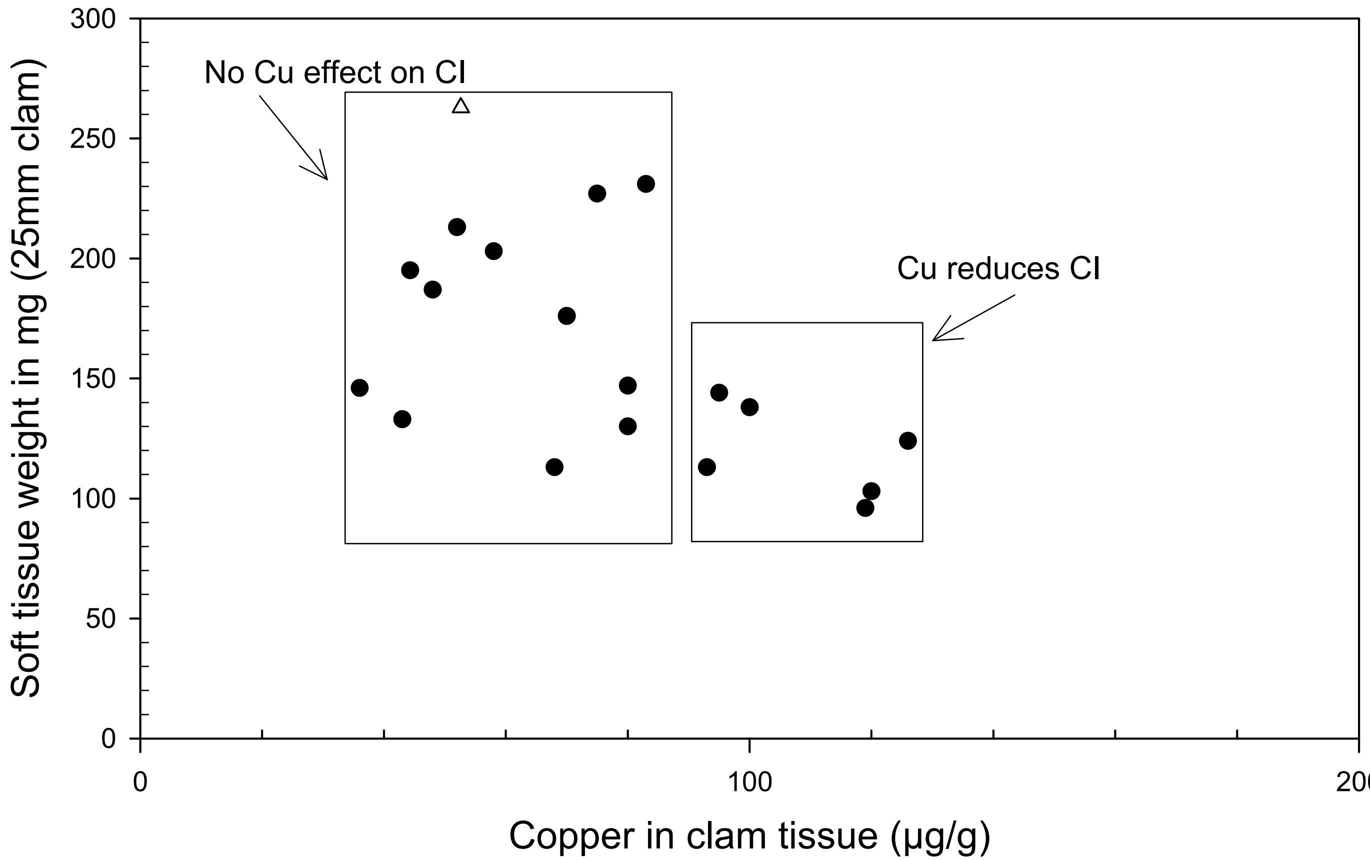


Figure 20. Correlation of maximum condition index (CI) *in Macoma balthica* vs. maximum copper concentrations in the months preceding the determination of maximum condition.

Data from Palo Alto sites is for the period from 1990 through 2002 (●) and 2003 (△).

Tables

Table 1. Sediment and environmental characteristics at the Palo Alto mudflat in 2003.

Units for Al, Fe, organic content and sand are percent dry weight. Monthly data are the mean ± standard deviation (std) for replicate subsamples (n=2). Means are summarized as the annual mean (the average of monthly means) and the standard error of the monthly means (SEM) (n=9).

Date	**Al** (percent)		**Fe** (percent)		**Organic** (percent)	**Sand** (percent)	**Salinity** (ppt)
	mean	std	mean	std			
January 14, 2003	7.0	0.1	4.9	0.069	1.7	5	22
February 24, 2003	6.4	0.06	4.6	0.00	1.5	47	21
March 25, 2003	6.7	0.0	4.8	0.00	1.1	21	22
April 22, 2003	6.0	0.1	4.5	0.04	1.4	50	26
May 5, 2003	5.2	0.10	4.1	0.00	1.2	52	25
June 4, 2003	5.6	0.2	4.4	0.0	1.3	44	28
September 11, 2003	5.0	0.1	3.9	0.01	1.0	75	30
October 9, 2003	4.3	0.1	3.5	0.02	0.8	61	29
December 18, 2003	5.1	0.0	4.0	0.01	1.0	52	20
Annual Mean:	**5.7**		**4.3**		**1.21**	**45**	**25**
SEM:	*0.3*		*0.2*		*0.10*	*7*	*1*

Table 2. Concentrations of trace elements in sediments at the Palo Alto mudflat in 2003.

Units are micrograms per gram dry weight. Monthly data are the mean ± standard deviation (std) for replicate subsamples (n=2). Means are summarized as the annual mean (the average of monthly means) and the standard error of the monthly means (SEM) (n=9). All concentrations except for silver (Ag) are based on near-total extracts (See Methods). Silver values are partial extracts.

Date	Ag		Cr		Cu		Hg	Ni		Se	V		Zn	
	mean	*STD*	*mean*	*STD*	*mean*	*STD*	*mean*	*mean*	*STD*	*mean*	*mean*	*STD*	*mean*	*STD*
January 14, 2003	0.29	0.01	188	3	44	1.3	0.24	104	1.5	0.48	166	3	159	4
February 24, 2003	0.36	0.01	180	4	37	0.9	0.29	96	1.1	0.38	152	0.2	141	4
March 25, 2003	0.35	0.01	184	3	41	1.0	0.30	101	1.3	0.42	159	3	152	4
April 22, 2003	0.27	0.03	167	9	37	1		95	0		152	1	139	5
May 5, 2003	0.28	0.00	144	6	31	0.1	0.31	86	1.5	0.45	140	1	120	0
June 4, 2003	0.27	0.02	159	14	36	0.4		91	1.3		146	2	134	1
September 11, 2003	0.24	0.01	158	13	28	0.5	0.29	80	0.19	0.26	127	3	112	3
October 9, 2003	0.26	0.00	132	6	22	1		72	0.7		120	2	99	1
December 18, 2003	0.46	0.01	152	4	28	0.5	0.27	82	0.6	0.27	132	1	115	2
Annual Mean:	**0.31**		**163**		**34**		**0.28**	**90**		**0.38**	**144**		**130**	
SEM:	***0.02***		***6***		***2***		***0.01***	***4***		***0.04***	***5***		***7***	

Table 3. Concentrations of trace elements in Macoma balthica at the Palo Alto mudflat in 2003.

All units are microgram per gram soft tissue dry weight. Condition index is the soft tissue weight in milligrams of a 25 mm shell length clam. Monthly data are the mean and standard error (*SEM) for replicate composite (n= 6-14). Means are summarized as the annual mean (the average of monthly means) and the standard error of the monthly means (SEM) (n=9).

Date		Ag	Cr	Cu	Hg	Ni	Se	Zn	Condition Index
January 14, 2003	*mean*	4.5	5.8	41	0.39	9.2	6.0	358	90
	**SEM*	0.4	0.7	3	0.03	0.5	0.2	21	
February 24, 2003	*mean*	3.0	4.1	30		6.4		327	106
	**SEM*	0.3	0.3	2		0.4		13	
March 25, 2003	*mean*	0.7	1.7	11		2.9		160	263
	**SEM*	0.1	0.1	0		0.1		7	
April 22, 2003	*mean*	0.5	1.7	11	0.13	3.0	3.3	190	236
	**SEM*	0.0	0.2	1	0.02	0.2	0.2	9	
May 5, 2003	*mean*	0.8	2.1	13		3.9		229	151
	**SEM*	0.2	0.2	1		0.2		15	
June 4, 2003	*mean*	0.7	1.1	16	0.20	3.3	3.5	211	201
	**SEM*	0.1	0.1	1	0.02	0.1	0.3	9	
September 11, 2003	*mean*	2.7	2.0	42	0.28	5.4	3.7	184	108
	**SEM*	0.3	0.1	5	0.03	0.5	0.4	7	
October 9, 2003	*mean*	3.3	3.0	47		6.4		253	117
	**SEM*	0.4	0.4	7		0.7		28	
December 18, 2003	*mean*	3.5	4.3	48		7.0		303	101
	**SEM*	0.3	0.5	5		0.6		31	
Annual Mean:		2.2	2.9	29	0.25	5.3	4.1	246	152
SEM:		0.5	0.5	5	0.06	0.7	0.6	23	22

Table 4. Annual mean copper (Cu) concentrations in clams and sediments at Palo Alto: January 1977 through December 2003.

Values are annual means from 7 to 12 collections per year and standard errors of those means for the year. Means are calculated between January and December. Units are microgram per gram dry weight of soft tissue for clams (Macoma balthica) and microgram per gram dry weight for sediment.

	Copper in sediment		**Copper**
Year	**HCl**	**Total**	**in clams**
1977	28±6	45±13	130±23
1978	42±11	57±13	187±104
1979	55±13	86±18	248±114
1980	47±5	66±9	287±66
1981	48±7	57±22	206±55
1982	35±4	34±24	168±35
1983	22±9	38±21	191±48
1984	26±10	40±16	159±55
1985	27±3	45±7	138±22
1986	24±3	49±9	114±49
1987	21±3	47±6	95±25
1988	27±3	53±5	53±24
1989	23±6	44±13	35±10
1990	23±2	51±4	35±11
1991	25±2	52±5	24±8
1992	27±6	52±5	46±14
1993	21±3	43±7	60±14
1994	19±2	45±4	59±12
1995	19±2	44±5	61±16
1996	19±2	43±4	71±11
1997	18±1	43±3	32±7
1998	20±1	46±2	35±4
1999	18±1	44±2	34±2
2000	18±1	39±3	32±3
2001	17±1	35±2	31±3
2002	13±1	38±2	36±4
2003	19±4	34±8	29±16

Table 5. Annual mean silver concentrations in clams and sediments at Palo Alto, January 1977 through December 2003.

Values are annual means from 7 to 12 collections per year and standard errors ofthose means for the year. Means are calculated between January and December. Units are microgram per gram dry weight of soft tissue for clams (Macoma balthica) and microgram per gram dry weight for sediment.

Year	Silver in sediment	Silver in clams
1977	0.65 ± 0.59	87 ± 21
1978	1.39 ± 0.35	106 ± 17
1979	1.62 ± 0.28	96 ± 29
1980	1.28 ± 0.38	105 ± 24
1981	1.41 ± 0.15	63 ± 18
1982	0.74 ± 0.21	45 ± 13
1983	0.56 ± 0.26	56 ± 11
1984	0.64 ± 0.20	57 ± 18
1985	0.78 ± 0.14	58 ± 6
1986	0.61 ± 0.14	50 ± 20
1987	ND	55 ± 18
1988	ND	20 ± 10
1989	ND	11 ± 4
1990	0.39 ± 0.09	7.7 ± 3.4
1991	0.25 ± 0.07	3.3± 2.0
1992	0.35 ± 0.11	5.9 ± 1.9
1993	0.36± 0.09	6.9 ± 3.2
1994	0.46 ± 0.07	5.4 ± 1.1
1995	0.27 ± 0.05	5.5 ± 1.2
1996	0.24 ± 0.06	7.5 ± 1.6
1997	0.34 ± 0.04	3.6 ± 1.0
1998	0.34 ± 0.04	3.3 ± 0.6
1999	0.22 ± 0.01	3.6 ± 0.3
2000	0.34 ± 0.02	3.0 ± 0.4
2001	0.43 ± 0.03	3.0 ± 0.4
2002	0.31 ± 0.02	3.0 ± 0.5
2003	0.49 ± 0.08	2.1 ± 1.5

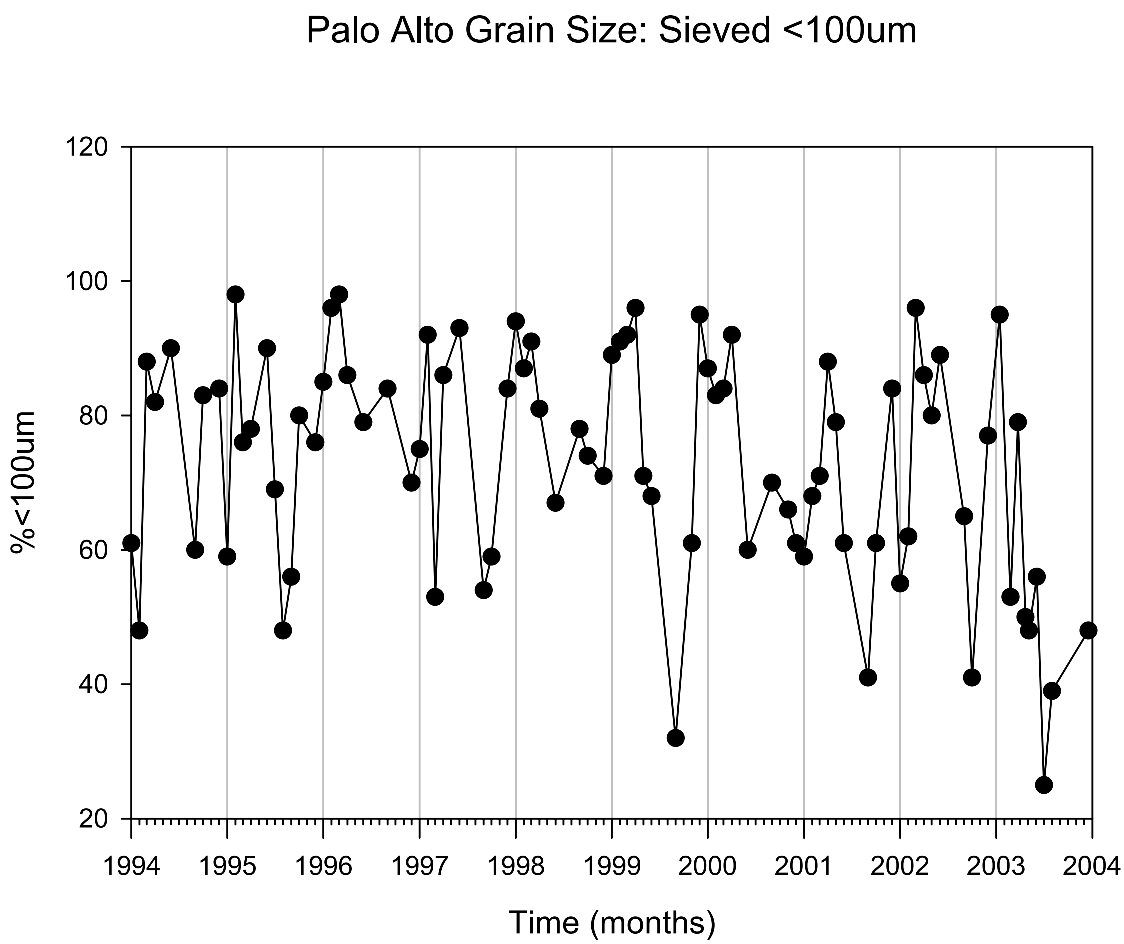
Appendix A.

Grain size (p. A-2) and total organic carbon (p. A-4) data. Concentrations of Hg and Se in surface sediments (p. 63) are reported in separate summary tables.

PALTO ALTO GRAIN SIZE DATA: <100um

Year	Date	%<100um
1994	01/10/94	61
	02/08/94	48
	03/22/94	88
	04/20/94	82
	06/13/94	90
	09/20/94	60
	10/17/94	83
	12/12/94	84
1995	01/18/95	59
	02/22/95	98
	03/27/95	76
	04/25/95	78
	06/06/95	90
	07/01/95	69
	08/01/95	48
	09/25/95	56
	10/24/95	80
	12/05/95	76
1996	01/17/96	85
	02/13/96	96
	03/13/96	98
	04/10/96	86
	06/18/96	79
	09/26/96	84
	12/09/96	70
1997	01/08/97	75
	02/19/97	92
	03/19/97	53
	04/14/97	86
	06/11/97	93
	09/17/97	54
	10/15/97	59
	12/09/97	84
1998	01/07/98	94
	02/04/98	87
	03/03/98	91
	04/13/98	81
	06/15/98	67
	09/09/98	78
	10/20/98	74
	12/14/98	71

Year	Date	%<100um
1999	01/15/99	89
	02/26/99	91
	03/22/99	92
	04/18/99	96
	05/19/99	71
	06/16/99	68
	09/13/99	32
	11/23/99	61
	12/20/99	95
2000	01/18/00	87
	02/15/00	83
	03/22/00	84
	04/10/00	92
	06/19/00	60
	09/13/00	70
	11/09/00	66
	12/12/00	61
2001	01/09/01	59
	02/05/01	68
	03/05/01	71
	04/10/01	88
	05/08/01	79
	06/12/01	61
	09/18/01	41
	10/15/01	61
	12/11/01	84
2002	01/08/02	55
	02/08/02	62
	03/07/02	96
	04/15/02	86
	05/15/02	80
	06/11/02	89
	09/09/02	65
	10/07/02	41
	12/16/02	77
2003	01/14/03	95
	02/24/03	53
	03/25/03	79
	04/22/03	50
	05/05/03	48
	06/04/03	56
	09/11/03	25
	10/09/03	39
	12/18/03	48


Palo Alto Grain Size: Sieved <100um
120
100
80
60
40
20
%<100um
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Time (months)

Carbon and Nitrogen analysis for 2003 Palo Alto surface sediments

Date	**%C**	**%N**	**d13C**	**d15N**
January 14, 2003	1.7	0.2	-24.1	9.7
February 24, 2003	1.5	0.2	-23.5	10.5
March 25, 2003	1.1	0.1	-23.9	10.4
April 22, 2003	1.4	0.2	-23.4	11.1
May 5, 2003	1.2	0.1	-23.6	8.6
June 4, 2003	1.3	0.2	-23.7	9.4
September 11, 2003	1.0	0.1	-23.6	9.8
October 9, 2003	0.8	0.1	-23.7	9.9
December 18, 2003	1.0	0.1	-23.7	10.2

Appendix B.

Metal concentrations determined by ICP-OES in sediments collected at the Palo Alto mudflat. Each monthly collection is reported on a separate page. Concentrations observed in the reconstituted samples or extracts (in micrograms per milliliter or µg/ml) are reported at the top of each page, along with the sediment weight and dilution factor. The latter are used to calculate concentrations in sediments (reported as microgram per gram dry sediment or µg/g). Replicate subsamples were analyzed from each collection. Mean and standard deviation for the replicate samples are reported for the near-total and hydrochloric acid extracts.

Palo Alto Total Extracts: 2002

1/08/2002: 55% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.5477	10	10	185.98	0.5	0.181	182.18	5.097	0.407	0.132	0.419	0.513
Tot2	0.5626	10	10	165.28	0.5	0.179	187.03	5.273	0.420	0.131	0.359	0.546
				33957	93	33.0	33263	930.5	74.4	24.1	76.4	93.7
				29378	90	31.8	33244	937.3	74.6	23.3	63.8	97.1
			Average	**31667**	**92**	**32.4**	**33253**	**933.9**	**74.5**	**23.7**	**70.1**	**95.4**
			Std	**3238**	**2**	**0.9**	**14**	**4.8**	**0.2**	**0.6**	**8.9**	**2.4**

2/08/2002: 62% < 100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.5621	10	10	233.20	0.7	0.225	232.09	7.511	0.524	0.168	0.468	0.698
Tot2	0.5463	10	10	228.19	0.7	0.220	229.31	7.352	0.513	0.163	0.479	0.677
				41488	121	40.0	41289	1336	93.2	30.0	83.2	124
				41769	119	40.2	41975	1346	93.9	29.8	87.6	124
			Average	**41629**	**120**	**40.1**	**41632**	**1341**	**93.5**	**29.9**	**85.4**	**124**
			Std	**199**	**1**	**0.2**	**485**	**7**	**0.5**	**0.1**	**3.1**	**0.1**

3/7/2002: 96% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.5534	10	10	265.64	0.7	0.254	237.35	7.961	0.538	0.178	0.508	0.722
Tot2	0.5673	10	10	280.34	0.7	0.267	248.72	8.297	0.560	0.180	0.541	0.762
				48001	125	46.0	42889	1439	97.2	32.1	91.8	130
				49417	131	47.1	43844	1463	98.6	31.8	95.3	134
			Average	**48709**	**128**	**46.5**	**43366**	**1451**	**97.9**	**31.9**	**93.6**	**132**
			Std	**1001**	**4**	**0.8**	**675**	**17**	**1.0**	**0.2**	**2.5**	**3**

4/15/2002: 86% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.5454	10	10	215.72	0.6	0.201	204.70	4.328	0.455	0.143	0.452	0.589
Tot2	0.5585	10	10	241.11	0.6	0.224	215.44	4.530	0.479	0.156	0.503	0.632
				39553	105	36.9	37532	793.6	83.5	26.1	82.8	108
				43170	113	40.2	38575	811.0	85.7	27.8	90.1	113
			Average	**41362**	**109**	**38.6**	**38054**	**802.3**	**84.6**	**27.0**	**86.4**	**111**
			Std	**2558**	**5**	**2.3**	**737**	**12.3**	**1.5**	**1.2**	**5.1**	**4**

5/15/2002: 80% < 100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.5781	10	10	249	0.7	0.236	228	4.686	0.511	0.160	0.498	0.677
Tot2	0.5804	10	10	253	0.7	0.242	228	4.696	0.511	0.163	0.513	0.669
				42990	114	40.9	39415	810.6	88.4	27.7	86.1	117
				43643	116	41.7	39215	809.1	88.1	28.0	88.4	115
			Average	**43317**	**115**	**41.3**	**39315**	**809.8**	**88.2**	**27.8**	**87.2**	**116**
			Std	**462**	**1**	**0.6**	**142**	**1.1**	**0.2**	**0.2**	**1.6**	**1**

6/11/2002: 89% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.5353	10	10	203	0.5	0.199	193	3.746	0.429	0.136	0.427	0.560
Tot2	0.5887	10	10	208	0.5	0.201	204	3.977	0.454	0.143	0.427	0.593
				37845	102	37.1	35976	699.7	80.1	25.3	79.7	105
				35283	88	34.1	34581	675.6	77.2	24.2	72.6	101
			Average	**36564**	**95**	**35.6**	**35279**	**687.7**	**78.6**	**24.8**	**76.2**	**103**
			Std	**1811**	**10**	**2.1**	**986**	**17.1**	**2.1**	**0.8**	**5.0**	**3**

9/09/2001: 65% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.6072	10	10	206	0.6	0.201	200	4.437	0.442	0.138	0.443	0.577
Tot2	0.5971	10	10	184	0.5	0.194	193	4.324	0.434	0.136	0.385	0.539
				33870	93	33.1	32889	730.7	72.7	22.7	72.9	95
				30878	88	32.4	32304	724.2	72.7	22.8	64.4	90
			Average	**32374**	**91**	**32.7**	**32597**	**727.4**	**72.7**	**22.7**	**68.7**	**93**
			Std	**2116**	**3**	**0.4**	**414**	**4.7**	**0.04**	**0.03**	**6.0**	**3**

10/07/2002: 41% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.5378	10	10	170	0.5	0.173	172	3.752	0.383	0.115	0.373	0.517
Tot2	0.5378	10	10	160	0.4	0.171	171	3.725	0.383	0.114	0.340	0.468
				31684	86	32.2	32029	697.6	71.2	21.3	69.4	96
				29715	84	31.8	31794	692.7	71.1	21.1	63.2	87
			Average	**30700**	**85**	**32.0**	**31911**	**695.2**	**71.2**	**21.2**	**66.3**	**92**
			Std	**1392**	**2**	**0.3**	**166**	**3.5**	**0.1**	**0.1**	**4.3**	**6**

12/17/2002: 77% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.5081	10	10	262	0.7	0.218	208.01	6.851	0.467	0.155	0.673	0.631
Tot2	0.5106	10	10	254	0.7	0.217	207.33	6.878	0.467	0.158	0.654	0.635
				51471	141	42.9	40938	1348	91.8	30.6	132	124
				49758	136	42.4	40606	1347	91.5	30.9	128	124
			Average	**50614**	**138**	**42.7**	**40772**	**1348**	**91.7**	**30.8**	**130**	**124**
			Std	**1211**	**3**	**0.3**	**235**	**1**	**0.2**	**0.3**	**3**	**0.2**

Palo Alto HCl Extracts: 2003

1/14/2003: 95% <100 µm

Sample	Weight (g)	Recon. (ml)		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.5374	10		0.035	161.50	-	1.312	332.20	54.260	0.412	0.951	0.686	2.976
HCL2	0.5116	10		0.033	152.20	-	1.250	314.50	51.600	0.393	0.914	0.651	2.829
				0.657	3005.2	-	24.41	6181.6	1009.68	7.67	17.7	12.8	55.38
				0.643	2975.0	-	24.43	6147.4	1008.60	7.69	17.9	12.7	55.30
			Average	**0.650**	**2990.1**	**-**	**24.42**	**6164.5**	**1009.14**	**7.678**	**17.8**	**12.7**	**55.34**
			Std	**0.007**	**15.1**	**-**	**0.01**	**17.1**	**0.54**	**0.008**	**0.1**	**0.01**	**0.04**

2/24/2003: 53% < 100 µm

Sample	Weight (g)	Recon. (ml)		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.509	10		0.030	138.80	-	1.009	298.20	50.690	0.351	0.852	0.578	2.540
HCL2	0.504	10		0.029	136.20	-	1.001	295.60	50.080	0.347	0.849	0.571	2.534
				0.597	2726.9	-	19.82	5858.5	995.87	6.89	16.7	11.3	49.90
				0.567	2702.4	-	19.86	5865.1	993.65	6.88	16.8	11.3	50.28
			Average	**0.582**	**2714.6**	**-**	**19.84**	**5861.8**	**994.76**	**6.885**	**16.8**	**11.3**	**50.09**
			Std	**0.015**	**12.3**	**-**	**0.02**	**3.3**	**1.11**	**0.006**	**0.1**	**0.01**	**0.19**

3/25/2003: 79% <100 µm

Sample	Weight (g)	Recon. (ml)		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.4961	10		0.022	143.20	-	1.131	319.70	27.100	0.396	0.926	0.634	2.750
HCL2	0.5424	10		0.025	151.80	-	1.238	337.60	29.350	0.412	0.988	0.678	2.968
				0.452	2886.5	-	22.80	6444.3	546.26	7.98	18.7	12.8	55.43
				0.463	2798.7	-	22.82	6224.2	541.11	7.59	18.2	12.5	54.72
			Average	**0.457**	**2842.6**	**-**	**22.81**	**6334.2**	**543.69**	**7.787**	**18.4**	**12.6**	**55.08**
			Std	**0.006**	**43.9**	**-**	**0.01**	**110.0**	**2.57**	**0.193**	**0.2**	**0.15**	**0.36**

4/22/2003: 50% <100 μm

Sample	Weight (g)	Recon. (ml)		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.5617	10		0.026	147.50	-	1.146	325.20	28.490	0.386	0.933	0.590	2.945
HCL2	0.5075	10		0.024	132.10	-	1.016	299.50	25.970	0.361	0.860	0.547	2.594
				0.465	2626.0	-	20.40	5789.6	507.21	6.88	16.6	10.5	52.43
				0.471	2603.0	-	20.02	5901.5	511.72	7.11	16.9	10.8	51.11
			Average	**0.468**	**2614.5**	**-**	**20.21**	**5845.5**	**509.47**	**6.99**	**16.8**	**10.6**	**51.77**
			Std	**0.003**	**12**	**-**	**0.19**	**56.0**	**2.26**	**0.12**	**0.2**	**0.1**	**0.66**

5/5/2003: 48% < 100 μm

Sample	Weight (g)	Recon. (ml)		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.5109	10		0.024	114.80	-	0.906	263.10	26.380	0.322	0.813	0.461	2.372
HCL2	0.5314	10		0.025	119.40	-	0.939	269.80	27.320	0.325	0.837	0.477	2.417
				0.464	2247.0	-	17.73	5149.7	516.34	6.31	15.9	9.0	46.43
				0.467	2246.9	-	17.67	5077.2	514.11	6.12	15.8	9.0	45.48
			Average	**0.465**	**2247.0**	**-**	**17.70**	**5113.4**	**515.23**	**6.22**	**15.8**	**9.0**	**45.96**
			Std	**0.001**	**0**	**-**	**0.03**	**36.3**	**1.12**	**0.09**	**0.1**	**0.0**	**0.47**

6/4/2003: 56% <100 μm

Sample	Weight (g)	Recon. (ml)		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.5493	10		0.028	134.20	-	1.167	287.70	24.420	0.344	0.899	0.503	2.831
HCl2	0.5378	10		0.027	134.30	-	1.142	286.70	24.160	0.344	0.903	0.496	2.764
				0.508	2443.1	-	21.25	5237.6	444.57	6.27	16.4	9.1	51.54
				0.502	2497.2	-	21.23	5331.0	449.24	6.40	16.8	9.2	51.39
			Average	**0.505**	**2470.2**	**-**	**21.24**	**5284.3**	**446.90**	**6.33**	**16.6**	**9.2**	**51.47**
			Std	**0.003**	**27**	**-**	**0.01**	**46.7**	**2.34**	**0.06**	**0.2**	**0.0**	**0.07**

9/11/2003: 25% <100 μm

Sample	Weight (g)	Recon. (ml)		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.5316	10		0.022	119.90	-	0.859	264.30	22.490	0.329	0.789	0.435	2.344
HCl2	0.5273	10		0.022	117.80	-	0.847	262.60	22.210	0.332	0.779	0.438	2.316
				0.414	2255.5	-	16.16	4971.8	423.06	6.19	14.8	8.2	44.09
				0.408	2234.0	-	16.07	4980.1	421.20	6.30	14.8	8.3	43.92
			Average	**0.411**	**2244.7**	**-**	**16.11**	**4975.9**	**422.13**	**6.24**	**14.8**	**8.2**	**44.01**
			Std	**0.003**	**11**	**-**	**0.05**	**4.2**	**0.93**	**0.06**	**0.0**	**0.1**	**0.09**

10/09/2003: 39% <100 µm

Sample	Weight (g)	Recon. (ml)		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.5118	10		0.021	96.30	-	0.648	220.00	29.530	0.280	0.715	0.363	1.884
HCl2	0.4943	10		0.020	94.19	-	0.626	210.00	27.250	0.277	0.674	0.349	1.815
				0.406	1882	-	12.7	4299	576.98	5.47	14.0	7.09	36.81
				0.413	1906	-	12.7	4248	551.28	5.61	13.6	7.06	36.72
			Average	**0.410**	**1894**	**-**	**12.7**	**4273**	**564.13**	**5.54**	**13.8**	**7.08**	**36.76**
			Std	**0.003**	**12**	**-**	**0.01**	**25**	**12.85**	**0.07**	**0.2**	**0.01**	**0.05**

12/18/2003: 47% <100 µm

Sample	Weight (g)	Recon. (ml)		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.5131	10		0.023	117.60	-	0.797	249.50	30.310	0.313	0.762	0.443	2.199
HCl2	0.5137	10		0.025	118.10	-	0.801	247.30	30.180	0.314	0.763	0.444	2.197
				0.456	2292	-	15.5	4863	590.72	6.11	14.9	8.64	42.86
				0.479	2299	-	15.6	4814	587.50	6.11	14.8	8.64	42.77
			Average	**0.467**	**2295**	**-**	**15.6**	**4838**	**589.11**	**6.11**	**14.9**	**8.64**	**42.81**
			Std	**0.011**	**4**	**-**	**0.03**	**24**	**1.61**	**0.00**	**0.0**	**0.00**	**0.04**

Appendix C.

Metal concentrations in the clam *Macoma balthica* collected at the Palo Alto Mudflat. Each monthly collection is reported on two pages. The first page contains summary statistics:

- Mean concentrations in microgram per gram dry tissue weight (μg/g).
- STD is the standard deviation of the mean.
- SEM is the standard error of the mean.
- CV percent is the coefficient of variation.
- r wt x [] is the correlation coefficient for the concentration versus weight correlation for each element.
- X 100mg is the concentration interpolated from the above regression for a 100 mg animal.
- r l x [] is the correlation coefficient for the concentration versus shell length regression.
- X 20 mm and X 25 mm are concentrations interpolated from the regression for 20mm and 25 mm animals.

Content (a measure of metal bioaccumulation that is standardized to tissue mass) is also shown for 20 and 25 mm animals, as is the weight determined for animals of 15 mm and 20 mm shell length.

The second page shows the analysis of each composite within the sample, the number of animals in each composite, concentration as calculated from sample dry weight and the dilution factor and the metal content for each composite.

Station: Palo Alto

Date: 01/14/03

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	4.480	0.5725	5.80	41.4	9.23	2.61	7.43	358.1
STD	0.9519	0.0803	1.62	7.37	1.14	0.464	1.87	46.24
SEM	0.4257	0.0359	0.726	3.29	0.509	0.207	0.835	20.68
CV%	21.25	14.02	28.0	17.8	12.3	17.8	25.1	12.91
n	5	5	5	5	5	5	5	5
r wt x [ ]	0.4112	0.5129	0.682	0.830	0.586	0.549	0.695	0.4819
X 100mg	2.823	0.7468	10.5	15.5	12.1	3.68	12.9	452.5
r l x [ ]	0.4801	0.4949	0.666	0.804	0.559	0.540	0.678	0.3848
X 15mm	4.711	0.5525	5.26	44.4	8.91	2.48	6.79	349.2
X 20mm	3.968	0.6171	7.01	34.8	9.94	2.89	8.85	378.1
X 25mm	3.224	0.6817	8.77	25.2	11.0	3.29	10.9	407.0

Estimated content (mg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.0944	0.0113	0.107	0.894	0.182	0.051	0.138	7.149
20mm	0.1824	0.0286	0.317	1.634	0.462	0.133	0.402	17.40
25mm	0.3040	0.0587	0.737	2.608	0.949	0.282	0.921	34.69

Estimated weight for 15mm clam

0.0204 gm
20.43 mg

Estimated weight for 20mm clam

0.0470 gm
47.00 mg

Estimated weight for 25mm clam

0.0897 gm
89.69 mg

Station: Palo Alto

Date: 01/14/03

Macoma balthica

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Concentration (ug/ml) - Blank Corrected from ICP-AES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	12.88	0.1551	0.0141	10	0.0812	0.0080	0.068	0.708	0.132	0.035	0.090	5.510
Mb2	15.12	0.1555	0.0194	10	0.0675	0.0093	0.096	0.699	0.138	0.044	0.122	5.772
Mb3	15.82	0.1593	0.0228	10	0.0861	0.0095	0.094	0.788	0.159	0.042	0.119	5.424
Mb4	17.96	0.2093	0.0349	10	0.0629	0.0099	0.089	0.708	0.167	0.044	0.120	6.248
Mb6	20.99	0.1678	0.0559	10	0.0741	0.0114	0.139	0.560	0.181	0.054	0.173	7.136
				LOD	0.0004	0.0001	0.002	0.004	0.001	0.004	0.002	0.001
				LOQ	0.002	0.0007	0.01	0.02	0.003	0.01	0.003	0.006

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mb1	5.235	0.5158	4.38	45.6	8.51	2.22	5.81	355.3
	Mb2	4.341	0.5981	6.20	44.9	8.86	2.86	7.87	371.2
	Mb3	5.405	0.5964	5.90	49.4	9.98	2.62	7.48	340.5
	Mb4	3.005	0.4730	4.27	33.8	8.00	2.09	5.71	298.5
	Mb6	4.416	0.6794	8.25	33.4	10.8	3.23	10.3	425.3

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mb1	0.0738	0.0073	0.062	0.644	0.120	0.031	0.082	5.01
	Mb2	0.0844	0.0116	0.121	0.873	0.172	0.056	0.153	7.22
	Mb3	0.1230	0.0136	0.134	1.13	0.227	0.060	0.170	7.75
	Mb4	0.1048	0.0165	0.149	1.18	0.279	0.073	0.199	10.4
	Mb6	0.2470	0.0380	0.462	1.87	0.604	0.181	0.576	23.8

Station: Palo Alto

Date: 02/24/03

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	3.041	0.3991	4.07	29.7	6.35	1.43	5.33	326.6
STD	0.8041	0.0610	0.832	5.41	1.04	0.299	1.03	37.75
SEM	0.2843	0.0216	0.294	1.91	0.369	0.106	0.362	13.35
CV%	26.44	15.28	20.4	18.2	16.4	20.9	19.2	11.56
n	8	8	8	8	8	8	8	8
r wt x [ ]	0.8974	0.4150	0.590	0.897	0.720	0.568	0.561	0.4591
X 100mg	4.437	0.4480	5.02	39.1	7.81	1.76	6.44	360.2
r l x [ ]	0.8845	0.3572	0.534	0.914	0.667	0.582	0.493	0.3198
X 15mm	2.605	0.3857	3.80	26.7	5.93	1.32	5.02	319.2
X 20mm	3.451	0.4116	4.32	32.6	6.76	1.53	5.62	333.6
X 25mm	4.298	0.4375	4.85	38.5	7.59	1.74	6.22	347.9

Estimated content (mg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.0778	0.0114	0.112	0.795	0.177	0.039	0.149	9.497
20mm	0.2061	0.0247	0.258	1.973	0.404	0.092	0.334	20.01
25mm	0.4389	0.0449	0.490	3.993	0.766	0.178	0.627	35.67

Estimated weight for 15mm clam

0.0296 gm
29.61 mg

Estimated weight for 20mm clam

0.0607 gm
60.70 mg

Estimated weight for 25mm clam

0.1059 gm
105.9 mg

Station: Palo Alto

Date: 02/24/03

Macoma balthica

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Concentration (ug/ml) - Blank Corrected from ICP-AES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	10.26	0.1715	0.0114	10	0.0332	0.0069	0.067	0.365	0.104	0.021	0.092	5.470
Mb2	14.09	0.2512	0.0251	10	0.0652	0.0082	0.072	0.632	0.129	0.029	0.099	9.059
Mb3	16.60	0.3729	0.0414	10	0.0939	0.0124	0.121	0.986	0.195	0.040	0.151	10.470
Mb4	17.64	0.3401	0.0425	10	0.1246	0.0139	0.149	1.123	0.198	0.051	0.190	10.920
Mb5	18.26	0.3569	0.0446	10	0.0953	0.0141	0.136	1.057	0.211	0.057	0.184	10.530
Mb6	19.02	0.2911	0.0582	10	0.0926	0.0151	0.159	1.000	0.218	0.057	0.203	10.150
Mb7	20.28	0.2406	0.0602	10	0.0774	0.0090	0.096	0.719	0.184	0.033	0.126	7.125
Mb8	24.44	0.2025	0.1013	10	0.0920	0.0088	0.098	0.771	0.153	0.033	0.128	7.929

		Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
	LOD	0.0004	0.0001	0.002	0.004	0.001	0.004	0.002	0.001
	LOQ	0.002	0.0007	0.01	0.02	0.003	0.01	0.003	0.006
	Sample #								
Concentration (ug/g) ==>	Mb1	1.936	0.4023	3.91	21.3	6.04	1.20	5.35	319.0
	Mb2	2.596	0.3264	2.88	25.1	5.15	1.13	3.93	360.6
	Mb3	2.518	0.3325	3.26	26.4	5.23	1.07	4.06	280.77
	Mb4	3.664	0.4087	4.39	33.0	5.81	1.51	5.58	321.08
	Mb5	2.670	0.3951	3.81	29.6	5.92	1.58	5.14	295.04
	Mb6	3.181	0.5187	5.47	34.4	7.50	1.96	6.97	348.68
	Mb7	3.217	0.3741	3.98	29.9	7.63	1.35	5.25	296.1
	Mb8	4.543	0.4346	4.85	38.1	7.54	1.63	6.33	391.6
	Sample #								
Content (ug) ==>	Mb1	0.0221	0.0046	0.045	0.243	0.069	0.014	0.061	3.647
	Mb2	0.0652	0.0082	0.072	0.632	0.129	0.029	0.099	9.059
	Mb3	0.1043	0.0138	0.135	1.10	0.217	0.044	0.168	11.633
	Mb4	0.1558	0.0174	0.187	1.40	0.247	0.064	0.237	13.650
	Mb5	0.1191	0.0176	0.170	1.32	0.264	0.071	0.230	13.163
	Mb6	0.1852	0.0302	0.318	2.00	0.437	0.114	0.406	20.300
	Mb7	0.1935	0.0225	0.239	1.80	0.459	0.082	0.316	17.81
	Mb8	0.4600	0.0440	0.491	3.85	0.764	0.166	0.641	39.65

Station: Palo ALto

Date: 03/25/03

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	0.6832	0.1893	1.70	10.9	2.87	0.673	2.03	160.2
STD	0.2500	0.0269	0.306	1.204	0.255	0.114	0.392	18.05
SEM	0.1020	0.0110	0.125	0.492	0.104	0.047	0.160	7.370
CV%	36.59	14.23	18.0	11.0	8.87	16.9	19.3	11.27
n	6	6	6	6	6	6	6	6
r wt x [ ]	0.9635	0.4644	0.437	0.976	0.205	0.701	0.586	0.6226
X 100mg	0.8395	0.1812	1.61	11.7	2.84	0.621	1.88	167.5
r l x [ ]	0.9307	0.4811	0.453	0.957	0.283	0.749	0.580	0.6075
X 15mm	0.6864	0.1891	1.70	10.9	2.87	0.672	2.03	160.4
X 20mm	0.9447	0.1747	1.55	12.2	2.79	0.577	1.78	172.6
X 25mm	1.203	0.1603	1.39	13.5	2.71	0.482	1.52	184.8

Estimated content (mg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.0312	0.0086	0.077	0.509	0.132	0.030	0.091	7.417
20mm	0.1116	0.0214	0.188	1.50	0.342	0.071	0.217	21.02
25mm	0.2995	0.0434	0.378	3.46	0.716	0.137	0.425	47.16

Estimated weight for 15mm clam

0.0461 gm
46.13 mg

Estimated weight for 20mm clam

0.1229 gm
122.9 mg

Estimated weight for 25mm clam

0.2629 gm
262.9 mg

Station: Palo ALto

Date: 03/25/03

Macoma balthica

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Concentration (ug/ml) - Blank Corrected from ICP-AES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	10.29	0.2288	0.0120	10	0.0124	0.0043	0.040	0.225	0.068	0.017	0.046	3.680
Mb2	11.76	0.3531	0.0208	10	0.0201	0.0083	0.076	0.364	0.117	0.030	0.094	5.588
Mb3	12.84	0.3382	0.0282	10	0.0177	0.0067	0.062	0.340	0.092	0.023	0.074	4.914
Mb4	14.02	0.4091	0.0372	10	0.0196	0.0065	0.053	0.445	0.105	0.024	0.068	5.613
Mb5	18.70	0.8703	0.0967	15	0.0517	0.0110	0.103	0.659	0.166	0.036	0.120	10.840
Mb6	22.02	1.1788	0.1684	20	0.0645	0.0098	0.084	0.773	0.166	0.032	0.093	10.200

		Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
	LOD	0.0004	0.0001	0.002	0.004	0.001	0.004	0.002	0.001
	LOQ	0.002	0.0007	0.01	0.02	0.003	0.01	0.003	0.006
	Sample #								
Concentration (ug/g) ==>	Mb1	0.5420	0.1879	1.73	9.8	2.95	0.747	2.03	160.8
	Mb2	0.5692	0.2351	2.15	10.3	3.32	0.858	2.66	158.3
	Mb3	0.5234	0.1981	1.85	10.1	2.72	0.671	2.20	145.3
	Mb4	0.4791	0.1589	1.29	10.9	2.58	0.589	1.66	137.2
	Mb5	0.8911	0.1896	1.77	11.4	2.86	0.627	2.06	186.83
	Mb6	1.094	0.1663	1.43	13.1	2.82	0.546	1.58	173.06
	Sample #								
Content (ug) ==>	Mb1	0.0065	0.0023	0.021	0.119	0.036	0.009	0.024	1.937
	Mb2	0.0118	0.0049	0.045	0.214	0.069	0.018	0.055	3.287
	Mb3	0.0148	0.0056	0.052	0.284	0.077	0.019	0.062	4.095
	Mb4	0.0178	0.0059	0.048	0.405	0.096	0.022	0.062	5.103
	Mb5	0.0862	0.0183	0.171	1.10	0.276	0.061	0.199	18.067
	Mb6	0.1843	0.0280	0.241	2.21	0.475	0.092	0.266	29.143

Station: Palo Alto

Date: 04/22/03

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	0.4845	0.1624	1.66	11.5	3.04	0.906	2.07	189.9
STD	0.0638	0.0394	0.519	1.36	0.533	0.172	0.542	23.99
SEM	0.0241	0.0149	0.196	0.515	0.201	0.065	0.205	9.066
CV%	13.16	24.25	31.2	11.9	17.5	19.0	26.2	12.63
n	7	7	7	7	7	7	7	7
r wt x [ ]	0.1967	0.7825	0.759	0.557	0.802	0.848	0.835	0.02
X 100mg	0.5057	0.1104	0.998	10.2	2.319	0.660	1.31	189.1
r l x [ ]	0.2409	0.8022	0.828	0.484	0.831	0.852	0.876	0.01
X 15mm	0.4812	0.1693	1.76	11.6	3.14	0.938	2.17	189.9
X 20mm	0.5104	0.1093	0.939	10.4	2.30	0.660	1.27	189.4
X 25mm	0.5396	0.0492	0.123	9.11	1.45	0.381	0.369	188.8

Estimated content (μg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.0169	0.0058	0.059	0.407	0.109	0.032	0.074	6.671
20mm	0.0521	0.0116	0.105	1.071	0.240	0.069	0.138	19.27
25mm	0.1248	0.0200	0.165	2.267	0.444	0.124	0.224	43.88

Estimated weight for 15mm clam

0.0353 gm
35.34 mg

Estimated weight for 20mm clam

0.1028 gm
102.8 mg

Estimated weight for 25mm clam

0.2355 gm
235.5 mg

Station: Palo Alto

Date: 04/22/03

Macoma balthica

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					Concentration (ug/ml) - Blank Corrected from ICP-AES							
Mb1	12.65	0.3543	0.0208	10	0.0148	0.0069	0.088	0.391	0.125	0.038	0.097	6.597
Mb2	13.66	0.273	0.0195	10	0.0162	0.0062	0.060	0.388	0.103	0.031	0.075	6.372
Mb3	14.48	0.3357	0.0305	10	0.0167	0.0060	0.061	0.400	0.114	0.035	0.077	6.487
Mb4	15.18	0.4021	0.0402	10	0.0175	0.0058	0.054	0.430	0.119	0.032	0.072	6.346
Mb5	15.51	0.3931	0.0437	10	0.0181	0.0058	0.056	0.414	0.109	0.032	0.073	6.847
Mb6	16.81	0.4448	0.0556	10	0.0198	0.0056	0.056	0.525	0.109	0.038	0.074	8.052
Mb7	20.72	0.3374	0.1125	10	0.0183	0.0040	0.038	0.343	0.082	0.022	0.047	6.859
				LOD	0.0004	0.0001	0.002	0.004	0.001	0.004	0.002	0.001
				LOQ	0.002	0.0007	0.01	0.02	0.003	0.01	0.003	0.006

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mb1	0.4177	0.1948	2.48	11.0	3.52	1.06	2.74	186.2
	Mb2	0.5934	0.2271	2.21	14.2	3.79	1.12	2.76	233.4
	Mb3	0.4975	0.1787	1.82	11.9	3.38	1.05	2.30	193.2
	Mb4	0.4352	0.1442	1.33	10.7	2.95	0.791	1.79	157.8
	Mb5	0.4604	0.1475	1.43	10.5	2.77	0.814	1.86	174.2
	Mb6	0.4451	0.1259	1.25	11.8	2.45	0.848	1.65	181.0
	Mb7	0.5424	0.1186	1.11	10.2	2.43	0.658	1.38	203.3

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mb1	0.0087	0.0041	0.052	0.230	0.073	0.022	0.057	3.881
	Mb2	0.0116	0.0044	0.043	0.277	0.074	0.022	0.054	4.551
	Mb3	0.0152	0.0055	0.056	0.363	0.103	0.032	0.070	5.897
	Mb4	0.0175	0.0058	0.054	0.430	0.119	0.032	0.072	6.346
	Mb5	0.0201	0.0064	0.063	0.460	0.121	0.036	0.081	7.608
	Mb6	0.0248	0.0070	0.070	0.656	0.136	0.047	0.092	10.07
	Mb7	0.0610	0.0133	0.125	1.143	0.274	0.074	0.155	22.86

Station: Palo Alto

Date: 05/05/03

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	0.7501	0.1927	2.06	13.3	3.88	1.16	2.33	228.9
STD	0.6529	0.0331	0.493	2.36	0.436	0.215	0.431	41.62
SEM	0.2308	0.0117	0.174	0.834	0.154	0.076	0.152	14.71
CV%	87.04	17.20	24.0	17.7	11.3	18.5	18.5	18.18
n	8	8	8	8	8	8	8	8
r wt x [ ]	0.9311	0.5042	0.639	0.864	0.503	0.918	0.754	0.4248
X 100mg	1.219	0.1798	1.81	14.9	4.05	1.01	2.08	242.5
r l x [ ]	0.9130	0.4998	0.644	0.875	0.493	0.918	0.755	0.4350
X 15mm	0.4198	0.2019	2.23	12.2	3.76	1.27	2.51	218.8
X 20mm	1.100	0.1829	1.87	14.5	4.00	1.04	2.14	239.5
X 25mm	1.781	0.1640	1.51	16.9	4.25	0.820	1.77	260.2

Estimated content (mg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.015	0.007	0.072	0.399	0.123	0.042	0.082	7.124
20mm	0.067	0.014	0.136	1.121	0.308	0.076	0.158	18.24
25mm	0.212	0.024	0.221	2.498	0.627	0.122	0.263	37.81

Estimated weight for 15mm clam

0.0326 gm
32.64 mg

Estimated weight for 20mm clam

0.0775 gm
77.45 mg

Estimated weight for 25mm clam

0.1514 gm
151.4 mg

Station: Palo Alto

Date: 05/05/03

Macoma balthica

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Concentration (ug/ml) - Blank Corrected from ICP-AES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	13.33	0.2523	0.0180	10	0.0178	0.0062	0.068	0.334	0.109	0.031	0.074	7.101
Mb2	14.83	0.4196	0.0350	10	0.0206	0.0084	0.095	0.506	0.152	0.054	0.104	8.719
Mb3	15.50	0.4131	0.0376	10	0.0207	0.0085	0.103	0.520	0.160	0.059	0.109	7.986
Mb4	16.06	0.4552	0.0455	10	0.0157	0.0087	0.099	0.489	0.164	0.056	0.113	9.139
Mb5	16.43	0.3793	0.0421	10	0.0165	0.0074	0.078	0.479	0.148	0.046	0.089	8.668
Mb6	17.05	0.3352	0.0419	10	0.0174	0.0067	0.069	0.461	0.124	0.039	0.080	8.125
Mb7	18.68	0.5559	0.0794	15	0.0246	0.0047	0.042	0.475	0.122	0.038	0.060	6.721
Mb8	27.55	0.5429	0.1810	15	0.0847	0.0064	0.059	0.678	0.169	0.026	0.065	10.690
				LOD	0.0004	0.0001	0.002	0.004	0.001	0.004	0.002	0.001
				LOQ	0.002	0.0007	0.01	0.02	0.003	0.01	0.003	0.006

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mb1	0.7055	0.2457	2.70	13.2	4.32	1.24	2.92	281.5
	Mb2	0.4909	0.2002	2.25	12.1	3.63	1.29	2.47	207.8
	Mb3	0.5011	0.2058	2.48	12.6	3.88	1.43	2.65	193.3
	Mb4	0.3449	0.1911	2.17	10.7	3.61	1.22	2.48	200.8
	Mb5	0.4350	0.1951	2.06	12.6	3.91	1.20	2.35	228.5
	Mb6	0.5191	0.1999	2.04	13.8	3.70	1.16	2.37	242.4
	Mb7	0.6638	0.1268	1.13	12.8	3.30	1.03	1.61	181.4
	Mb8	2.340	0.1768	1.62	18.7	4.67	0.707	1.79	295.36

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mb1	0.0127	0.0044	0.049	0.238	0.078	0.022	0.053	5.072
	Mb2	0.0172	0.0070	0.079	0.422	0.127	0.045	0.086	7.266
	Mb3	0.0188	0.0077	0.093	0.473	0.146	0.054	0.099	7.260
	Mb4	0.0157	0.0087	0.099	0.489	0.164	0.056	0.113	9.139
	Mb5	0.0183	0.0082	0.087	0.532	0.165	0.051	0.099	9.631
	Mb6	0.0218	0.0084	0.086	0.577	0.155	0.049	0.100	10.16
	Mb7	0.0527	0.0101	0.090	1.019	0.262	0.082	0.128	14.40
	Mb8	0.4235	0.0320	0.293	3.390	0.846	0.128	0.325	53.450

Station: Palo Alto

Date: 06/04/03

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	0.7406	0.1366	1.12	16.1	3.26	0.874	1.44	211.1
STD	0.1617	0.0181	0.163	1.76	0.307	0.173	0.148	24.20
SEM	0.0572	0.0064	0.058	0.622	0.108	0.061	0.052	8.555
CV%	21.83	13.25	14.6	10.9	9.41	19.8	10.2	11.46
n	8	8	8	8	8	8	8	8
r wt x [ ]	0.7022	0.8077	0.770	0.835	0.932	0.863	0.715	0.3840
X 100mg	0.8486	0.1227	0.996	14.7	2.99	0.732	1.34	219.9
r l x [ ]	0.6151	0.8764	0.840	0.817	0.970	0.908	0.791	0.3345
X 15mm	0.6680	0.1482	1.21	17.1	3.48	0.988	1.53	205.2
X 20mm	0.8337	0.1217	0.987	14.7	2.98	0.727	1.33	218.7
X 25mm	0.9995	0.0953	0.760	12.3	2.49	0.465	1.14	232.2

Estimated content (μg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.0197	0.0044	0.036	0.503	0.102	0.029	0.045	6.006
20mm	0.0698	0.0104	0.084	1.264	0.256	0.061	0.114	18.79
25mm	0.1861	0.0204	0.164	2.582	0.522	0.108	0.237	45.53

Estimated weight for 15mm clam

0.0293 gm
29.33 mg

Estimated weight for 20mm clam

0.0867 gm
86.71 mg

Estimated weight for 25mm clam

0.2010 gm
201.0 mg

Station: Palo Alto

Date: 06/04/03

Macoma balthica

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					Concentration (ug/ml) - Blank Corrected from ICP-AES							
Mb1	13.49	0.2855	0.0204	10	0.0201	0.0046	0.036	0.500	0.104	0.032	0.045	6.429
Mb2	15.33	0.3679	0.0368	10	0.0248	0.0053	0.048	0.607	0.126	0.035	0.060	6.480
Mb3	15.63	0.3059	0.0306	10	0.0272	0.0045	0.039	0.558	0.108	0.028	0.047	7.029
Mb4	15.98	0.3241	0.0360	10	0.0190	0.0047	0.036	0.497	0.106	0.028	0.046	6.256
Mb5	17.17	0.3549	0.0444	10	0.0247	0.0049	0.035	0.620	0.118	0.031	0.047	8.261
Mb6	17.75	0.3767	0.0538	10	0.0257	0.0052	0.044	0.611	0.118	0.037	0.057	7.095
Mb7	18.71	0.3602	0.0720	10	0.0223	0.0039	0.035	0.516	0.112	0.025	0.046	7.273
Mb8	23.46	0.486	0.1620	15	0.0348	0.0036	0.028	0.423	0.086	0.018	0.040	7.828
				LOD	0.0004	0.0001	0.002	0.004	0.001	0.004	0.002	0.001
				LOQ	0.002	0.0007	0.01	0.02	0.003	0.01	0.003	0.006

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mb1	0.7040	0.1611	1.27	17.5	3.65	1.13	1.58	225.2
	Mb2	0.6741	0.1441	1.30	16.5	3.42	0.962	1.62	176.1
	Mb3	0.8892	0.1471	1.27	18.2	3.54	0.922	1.55	229.8
	Mb4	0.5862	0.1450	1.10	15.3	3.27	0.864	1.43	193.0
	Mb5	0.6960	0.1381	0.983	17.5	3.31	0.871	1.32	232.8
	Mb6	0.6822	0.1380	1.17	16.2	3.12	0.974	1.52	188.3
	Mb7	0.6191	0.1083	0.958	14.3	3.11	0.700	1.28	201.9
	Mb8	1.074	0.1111	0.870	13.0	2.66	0.568	1.24	241.6

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mb1	0.0144	0.0033	0.026	0.357	0.074	0.023	0.032	4.592
	Mb2	0.0248	0.0053	0.048	0.607	0.126	0.035	0.060	6.480
	Mb3	0.0272	0.0045	0.039	0.558	0.108	0.028	0.047	7.029
	Mb4	0.0211	0.0052	0.040	0.552	0.118	0.031	0.051	6.951
	Mb5	0.0309	0.0061	0.044	0.775	0.147	0.039	0.058	10.33
	Mb6	0.0367	0.0074	0.063	0.873	0.168	0.052	0.082	10.14
	Mb7	0.0446	0.0078	0.069	1.03	0.224	0.050	0.092	14.55
	Mb8	0.1740	0.0180	0.141	2.11	0.431	0.092	0.201	39.14

Station: Palo Alto

Date: 09/11/02

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	2.652	0.2677	2.02	41.8	5.45	1.25	2.75	183.8
STD	0.8303	0.0370	0.358	11.697	1.16	0.253	0.531	17.64
SEM	0.3390	0.0151	0.146	4.78	0.473	0.103	0.217	7.202
CV%	31.31	13.84	17.8	28.0	21.3	20.2	19.3	9.595
n	6	6	6	6	6	6	6	6
r wt x [ ]	0.5588	0.0203	0.435	0.585	0.672	0.335	0.419	0.0435
X 100mg	3.472	0.2664	2.29	29.7	6.823	1.10	3.15	185.2
r l x [ ]	0.4229	0.1567	0.295	0.690	0.561	0.466	0.276	0.0139
X 15mm	2.330	0.2730	1.92	49.2	4.85	1.36	2.62	184.1
X 20mm	2.813	0.2650	2.07	38.1	5.75	1.20	2.82	183.7
X 25mm	3.297	0.2571	2.21	27.0	6.64	1.04	3.02	183.4

Estimated content (µg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.0435	0.0051	0.036	0.920	0.091	0.025	0.049	3.411
20mm	0.1330	0.0131	0.101	1.822	0.281	0.058	0.138	9.135
25mm	0.3165	0.0272	0.228	3.095	0.675	0.112	0.309	19.61

Estimated weight for 15mm clam

0.0186 gm
18.55 mg

Estimated weight for 20mm clam

0.0500 gm
50.00 mg

Estimated weight for 25mm clam

0.1079 gm
107.9 mg

Station: Palo Alto

Date: 09/11/02

Macoma balthica

Sample #-n	Average Length (mm)	Total Dry Wt (gm	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					Concentration (ug/ml) - Blank Corrected from ICP-AES							
Mb1	14.63	0.2075	0.0148	10	0.0655	0.0068	0.048	1.292	0.124	0.034	0.067	4.155
Mb2	16.45	0.2281	0.0285	10	0.0634	0.0062	0.048	1.121	0.130	0.034	0.067	4.540
Mb3	16.97	0.2834	0.0315	10	0.0733	0.0074	0.056	1.098	0.134	0.035	0.075	4.512
Mb4	17.98	0.2766	0.0346	10	0.0469	0.0061	0.043	0.930	0.116	0.026	0.058	4.551
Mb5	18.81	0.2323	0.0387	10	0.0419	0.0056	0.039	0.796	0.110	0.025	0.052	4.417
Mb6	25.16	0.3204	0.1068	10	0.1247	0.0091	0.079	1.055	0.236	0.038	0.110	6.085

		Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
	LOD	0.0004	0.0001	0.002	0.004	0.001	0.004	0.002	0.001
	LOQ	0.002	0.0007	0.01	0.02	0.003	0.01	0.003	0.006
	Sample #								
Concentration (ug/g) ==>	Mb1	3.157	0.3277	2.32	62.27	5.98	1.61	3.21	200.2
	Mb2	2.779	0.2718	2.10	49.15	5.70	1.47	2.93	199.0
	Mb3	2.586	0.2611	1.97	38.74	4.73	1.24	2.64	159.2
	Mb4	1.696	0.2205	1.54	33.6	4.18	0.933	2.09	164.5
	Mb5	1.804	0.2411	1.70	34.3	4.72	1.07	2.23	190.1
	Mb6	3.892	0.2840	2.48	32.93	7.38	1.19	3.42	189.9
	Sample #								
Content (ug) ==>	Mb1	0.0468	0.0049	0.034	0.9229	0.089	0.024	0.048	2.968
	Mb2	0.0793	0.0078	0.060	1.401	0.163	0.042	0.084	5.675
	Mb3	0.0814	0.0082	0.062	1.220	0.149	0.039	0.083	5.013
	Mb4	0.0586	0.0076	0.053	1.16	0.145	0.032	0.072	5.689
	Mb5	0.0698	0.0093	0.066	1.33	0.183	0.042	0.087	7.362
	Mb6	0.4157	0.0303	0.264	3.517	0.788	0.127	0.365	20.28

Station: Palo Alto

Date: 10/09/03

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	3.272	0.3391	3.03	47.5	6.44	1.72	3.74	253.0
STD	1.102	0.1204	1.14	19.3	1.94	0.788	1.45	79.36
SEM	0.3896	0.0426	0.404	6.84	0.687	0.279	0.512	28.06
CV%	33.68	35.52	37.8	40.7	30.2	46.0	38.7	31.37
n	8	8	8	8	8	8	8	8
r wt x [ ]	0.5381	0.7317	0.502	0.472	0.626	0.684	0.711	0.4773
X 100mg	2.668	0.2493	2.44	38.2	5.20	1.17	2.69	214.3
r l x [ ]	0.6894	0.8537	0.648	0.667	0.778	0.825	0.819	0.5329
X 15mm	4.136	0.4561	3.87	62.1	8.15	2.46	5.08	301.0
X 20mm	3.221	0.3322	2.98	46.6	6.33	1.67	3.66	250.1
X 25mm	2.305	0.2083	2.08	31.1	4.51	0.887	2.23	199.1

Estimated content (μg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.0488	0.0055	0.045	0.728	0.098	0.030	0.062	3.542
20mm	0.1310	0.0133	0.119	1.851	0.259	0.064	0.145	10.16
25mm	0.2820	0.0262	0.253	3.818	0.553	0.118	0.281	23.00

Estimated weight for 15mm clam

0.0119 gm
11.91 mg

Estimated weight for 20mm clam

0.0432 gm
43.21 mg

Estimated weight for 25mm clam

0.1174 gm
117.4 mg

Station: Palo Alto

Date: 10/09/03

Macoma balthica

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Concentration (ug/ml) - Blank Corrected from ICP-AES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	14.19	0.1281	0.0075	10	0.0721	0.0071	0.054	1.110	0.131	0.039	0.073	5.137
Mb2	15.83	0.1606	0.0161	10	0.0668	0.0080	0.084	1.062	0.140	0.045	0.101	4.108
Mb3	17.33	0.1784	0.0255	10	0.0532	0.0053	0.041	0.773	0.107	0.028	0.058	4.429
Mb4	18.50	0.2363	0.0338	10	0.0629	0.0076	0.075	0.949	0.131	0.039	0.086	5.719
Mb5	20.35	0.2643	0.0529	10	0.0596	0.0076	0.056	0.801	0.135	0.029	0.073	3.405
Mb6	21.66	0.2298	0.0575	10	0.0704	0.0062	0.053	0.870	0.130	0.028	0.068	6.209
Mb7	22.83	0.3055	0.0764	10	0.0840	0.0083	0.069	0.953	0.158	0.039	0.093	8.954
Mb8	27.06	0.4577	0.1526	15	0.0817	0.0065	0.079	1.348	0.155	0.032	0.069	5.627
				LOD	0.0004	0.0001	0.002	0.004	0.001	0.004	0.002	0.001
				LOQ	0.002	0.0007	0.01	0.02	0.003	0.01	0.003	0.006

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mb1	5.628	0.5543	4.25	86.65	10.2	3.07	5.68	401.0
	Mb2	4.159	0.4981	5.26	66.13	8.74	2.81	6.28	255.8
	Mb3	2.982	0.2971	2.31	43.3	5.98	1.57	3.25	248.3
	Mb4	2.662	0.3216	3.16	40.1	5.55	1.65	3.62	242.0
	Mb5	2.255	0.2876	2.12	30.3	5.10	1.08	2.78	128.8
	Mb6	3.064	0.2698	2.29	37.8	5.65	1.21	2.98	270.2
	Mb7	2.750	0.2717	2.25	31.2	5.16	1.28	3.05	293.1
	Mb8	2.678	0.2130	2.58	44.18	5.09	1.05	2.25	184.4

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mb1	0.0424	0.0042	0.032	0.6529	0.077	0.023	0.043	3.022
	Mb2	0.0668	0.0080	0.084	1.062	0.140	0.045	0.101	4.108
	Mb3	0.0760	0.0076	0.059	1.10	0.152	0.040	0.083	6.327
	Mb4	0.0899	0.0109	0.107	1.36	0.187	0.056	0.122	8.170
	Mb5	0.1192	0.0152	0.112	1.60	0.270	0.057	0.147	6.810
	Mb6	0.1760	0.0155	0.132	2.17	0.325	0.070	0.171	15.52
	Mb7	0.2100	0.0208	0.172	2.38	0.394	0.098	0.233	22.39
	Mb8	0.4085	0.0325	0.394	6.740	0.777	0.161	0.344	28.14

Station: Palo Alto

Date: 12/18/03

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	3.508	0.4066	4.28	48.0	6.97	2.04	5.65	302.5
STD	0.7170	0.1088	1.15	12.5	1.43	0.662	1.47	75.80
SEM	0.2927	0.0444	0.471	5.09	0.585	0.270	0.602	30.94
CV%	20.44	26.76	27.0	26.0	20.6	32.4	26.1	25.05
n	6	6	6	6	6	6	6	6
r wt x [ ]	0.3826	0.8325	0.769	0.864	0.849	0.861	0.816	0.6527
X 100mg	3.166	0.2938	3.17	34.5	5.46	1.33	4.15	241.0
r l x [ ]	0.5267	0.8880	0.813	0.925	0.887	0.915	0.861	0.6971
X 15mm	3.997	0.5317	5.49	62.9	8.62	2.83	7.29	370.9
X 20mm	3.530	0.4122	4.33	48.6	7.05	2.08	5.72	305.6
X 25mm	3.063	0.2928	3.17	34.4	5.48	1.33	4.15	240.3

Estimated content (μg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.054	0.007	0.076	0.875	0.118	0.040	0.101	5.030
20mm	0.143	0.016	0.171	1.930	0.284	0.081	0.227	12.23
25mm	0.305	0.030	0.321	3.565	0.560	0.138	0.424	24.38

Estimated weight for 15mm clam

0.0134 gm
13.38 mg

Estimated weight for 20mm clam

0.0417 gm
41.71 mg

Estimated weight for 25mm clam

0.1007 gm
100.7 mg

Station: Palo Alto

Date: 12/18/03

Macoma balthica

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					Concentration (ug/ml) - Blank Corrected from ICP-AES							
Mb1	14.92	0.1832	0.0141	10	0.0818	0.0101	0.103	1.187	0.159	0.055	0.137	7.419
Mb2	17.34	0.1816	0.0227	10	0.0705	0.0092	0.100	1.040	0.155	0.047	0.129	4.700
Mb4	18.42	0.1667	0.0278	10	0.0547	0.0064	0.063	0.884	0.108	0.032	0.085	6.287
Mb5	21.33	0.2722	0.0544	10	0.0666	0.0099	0.111	0.995	0.185	0.051	0.147	7.088
Mb7	24.06	0.3643	0.0911	10	0.1419	0.0141	0.155	1.578	0.233	0.067	0.196	11.150
Mb8	25.34	0.316	0.1053	10	0.0972	0.0078	0.079	1.036	0.156	0.034	0.108	6.568
Mb3	17.98	0.2478	0.0310									
Mb6	22.26	0.3093	0.06186									

Mb3 & Mb6 spilled during analysis

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
LOD	0.0004	0.0001	0.002	0.004	0.001	0.004	0.002	0.001
LOQ	0.002	0.0007	0.01	0.02	0.003	0.01	0.003	0.006

Concentration (ug/g) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	4.465	0.5513	5.61	64.79	8.70	2.99	7.49	405.0
Mb2	3.882	0.5066	5.48	57.27	8.55	2.57	7.09	258.8
Mb3	3.281	0.3839	3.76	53.0	6.48	1.92	5.10	377.1
Mb4	2.447	0.3637	4.07	36.6	6.78	1.88	5.40	260.4
Mb5	3.895	0.3870	4.24	43.32	6.40	1.83	5.37	306.07
Mb6	3.076	0.2468	2.51	32.78	4.92	1.08	3.43	207.8

Content (ug) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	0.0629	0.0078	0.079	0.9131	0.123	0.042	0.106	5.707
Mb2	0.0881	0.0115	0.125	1.300	0.194	0.058	0.161	5.875
Mb3	0.0912	0.0107	0.104	1.47	0.180	0.053	0.142	10.48
Mb4	0.1332	0.0198	0.221	1.99	0.369	0.103	0.294	14.18
Mb5	0.3548	0.0353	0.387	3.945	0.583	0.167	0.489	27.875
Mb6	0.3240	0.0260	0.264	3.453	0.519	0.113	0.361	21.89

Appendix D.

Concentrations of Hg and Se in surface sediments and clams from Palo Alto (D-2) and in standard reference materials (D-3).

Palo Alto surface sediments, Hg and Se analysis: 2003

Date	mean Hg (μg/g)	mean Se (μg/g)
January 14, 2003	0.24	0.48
February 24, 2003	0.29	0.38
April 22, 2003	0.30	0.42
June 4, 2003	0.31	0.45
September 11, 2003	0.29	0.26
December 18, 2003	0.27	0.27

Palo Alto *Macoma balthica*, Hg analysis: 2003

Sample ID	mean Hg (μg/g)	SEM
January 14, 2003	0.39	0.03
April 22, 2003	0.13	0.02
June 4, 2003	0.20	0.02
September 11, 2003	0.28	0.03

Palo Alto *Macoma balthica*, Se analysis: 2003.

Sample ID	mean Se (μg/g)	SEM
January 14, 2003	6.00	0.20
April 22, 2003	3.32	0.19
June 4, 2003	3.50	0.25
September 11, 2003	3.70	0.44

Standard reference materials (SRM) with accepted and found concentrations. Se and Hg analysis 2003:

SRM		Hg	Se
NIST 2709	Accepted	1.40±0.08	1.57±0.08
	Found	1.4	1.5
NIST 2711	Accepted	6.25±0.19	1.52±0.14
	Found	6.1	1.4
NIST 1646A	Accepted	0.04	0.19±0.03
	Found	0.03	0.2
USGS MAG-1	Accepted	0.018	1.16±0.12
	Found	0.02	1.1
USGS STM-1	Accepted	0.015	0.008±0.002
	Found	0.02	<0.1
USGS SDO-1	Accepted	0.19±0.08	1.9-6.8
	Found	0.16	1.9
USGS SGR-1	Accepted	0.313	3.5±0.28
	Found	0.28	3.4
USGS SCO-1	Accepted	0.052	0.89±0.06
	Found	0.07	0.9
USGS QLO-1	Accepted	0.007	0.009±0.002
	Found	0.02	<0.1

Appendix E.

Analysis of (NIST) reference materials. 2003 SRM 2709 (San Joaquin Soil) recoveries (HNO_3 extraction) (E-2). Metal concentrations analyzed (at each sampling) in Standard Reference Material (NIST) 2976 (Mussel tissue) compared to certified mean, maximum and minimum values for that material (E-3)

2003 SRM 2709 Recoveries *Concentration, ug/g*

Month	Rep	AL	CR	CU	FE	MN	NI	PB	V	ZN
January	1	45627	113.3	21.8	33712	540	77.9	14.8	124.6	71.2
	2	45013	112.9	22.0	33333	535	76.7	15.9	123.6	73.7
February	1	44230	111.5	22.5	33437	543	77.0	14.7	123.9	73.6
	2	45232	119.0	21.7	34235	554	77.7	15.1	125.9	72.0
March	1	43954	113.2	21.7	34169	547	79.2	15.0	123.6	71.8
	2	45752	127.1	22.7	34662	557	79.1	16.1	128.8	75.8
April	1	43361	110.6	20.8	34111	554	78.5	14.3	126.7	69.6
	2	44589	123.0	22.1	34408	554	78.2	14.4	129.0	74.5
May	1	44497	120.7	21.9	34318	554	77.5	15.7	128.0	71.4
	2	43417	120.5	21.2	33743	547	77.7	14.5	126.4	70.7
June	1	43657	103.3	20.8	31506	506	75.2	15.1	116.8	81.9
	2	45083	107.3	21.7	32155	516	75.0	16.0	120.3	84.5
September	1	42606	92.9	20.9	30465	485	72.8	14.5	117.3	79.4
	2	43188	88.6	21.0	30567	494	70.9	13.9	121.9	74.2
October	1	43269	90.6	20.8	30166	489	68.5	14.3	117.8	71.0
	2	42723	85.8	20.5	30209	492	69.1	14.6	118.4	73.2
December	1	43724	91.7	21.2	30671	498	69.7	14.9	119.9	76.0
	2	42579	91.6	21.2	30115	487	68.4	13.9	118.9	75.0
Certified Value, ug/g		**75000**	**130.00**	**34.60**	**35000**	**538**	**88.0**	**18.9**	**112.0**	**106.0**
Standard Deviation		**0**	**4.00**	**0.70**	**0**	**17**	**5.0**	**0.5**	**5.0**	**3.0**

Month	Rep	AL	CR	CU	FE	MN	NI	PB	V	ZN
January	1	61	87.14	62.99	96	100	88.58	78.16	111.21	67.17
	2	60	86.86	63.72	95	99	87.17	83.95	110.40	69.52
February	1	59	85.79	64.97	96	101	87.45	77.85	110.61	69.47
	2	60	91.50	62.60	98	103	88.28	80.02	112.40	67.97
March	1	59	87.07	62.83	98	102	90.04	79.13	110.33	67.75
	2	61	97.77	65.74	99	104	89.91	85.23	114.98	71.53
April	1	58	85.07	59.98	97	103	89.24	75.53	113.16	65.70
	2	59	94.59	63.75	98	103	88.91	76.21	115.18	70.31
June	1	59	92.87	63.16	98	103	88.02	82.82	114.28	67.37
	2	58	92.71	61.33	96	102	88.35	76.68	112.83	66.68
September	1	57	71.50	60.34	87	90	82.70	76.58	104.70	74.92
	2	58	68.15	60.57	87	92	80.57	73.62	108.84	70.04
October	1	58	69.73	59.99	86	91	77.79	75.51	105.21	66.98
	2	57	65.96	59.13	86	91	78.57	77.10	105.71	69.04
December	1	58	70.53	61.26	88	93	79.18	78.85	107.02	71.68
	2	57	70.49	61.33	86	90	77.71	73.79	106.19	70.73
Average % Recovery		**59**	**82.36**	**62.11**	**93**	**98**	**85.15**	**78.19**	**110.19**	**69.18**
Standard Deviation		**1**	**10.96**	**1.91**	**5**	**5**	**4.78**	**3.40**	**3.55**	**2.36**

2003 SRM 2976 Recoveries

Date	Cadmium	Chromium	Copper	Lead	Nickel	Silver	Vanadium	Zinc
January 14, 2003	0.69	0.57	3.35	1.03	0.74	0.001	0.79	136
February 24, 2003	0.71	0.49	3.58	0.83	0.74	0.004	0.78	130
March 25, 2003	0.69	0.48	3.27	0.91	0.69	0.022	0.75	127
April 22, 2003	0.73	0.55	3.32	0.74	0.74	0.007	0.81	130
May 5, 2003	0.71	0.48	3.33	0.76	0.71	0.009	0.77	130
June 4, 2003	0.67	0.49	3.43	0.70	0.65	0.013	0.72	128
September 11, 2003	0.70	0.51	3.45	0.71	0.71	0.013	0.78	131
October 9, 2003	0.72	0.50	3.44	0.74	0.72	0.007	0.80	133
December 18, 2003	0.76	0.51	3.77	0.88	0.75	0.010	0.84	142
Mean	0.71	0.51	3.44	0.81	0.72	0.009	0.78	132
STD	0.03	0.03	0.15	0.11	0.03	0.006	0.03	4

Certified Values

Mean	0.82	0.5	4.02	1.19	0.93	0.011	not certified	137
Max.	0.98	0.66	4.35	1.37	1.05	0.016	"	150
Min.	0.66	0.37	3.69	1.01	0.81	0.006	"	124

Appendix F.

Method limits of detection and limits of quantification. Limits were determined using serial dilutions of extracts of NIST SRM 2711 for the sediment methods and NIST SRM 2976 for the clam method.

Sediment Partial Extract Analysis:

	Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
LOD	0.001	0.02	0.006	0.003	0.005	0.0005	0.0006	0.004	0.0008	0.004
LOQ	0.004	0.80	0.02	0.008	0.020	0.002	0.002	0.01	0.003	0.01

Sediment Total Extract Analysis:

		Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
LOD		0.02	0.01	0.003	0.005	0.0006	0.0003	0.005	0.001	0.002
LOQ		0.60	0.03	0.01	0.020	0.002	0.001	0.02	0.004	0.007

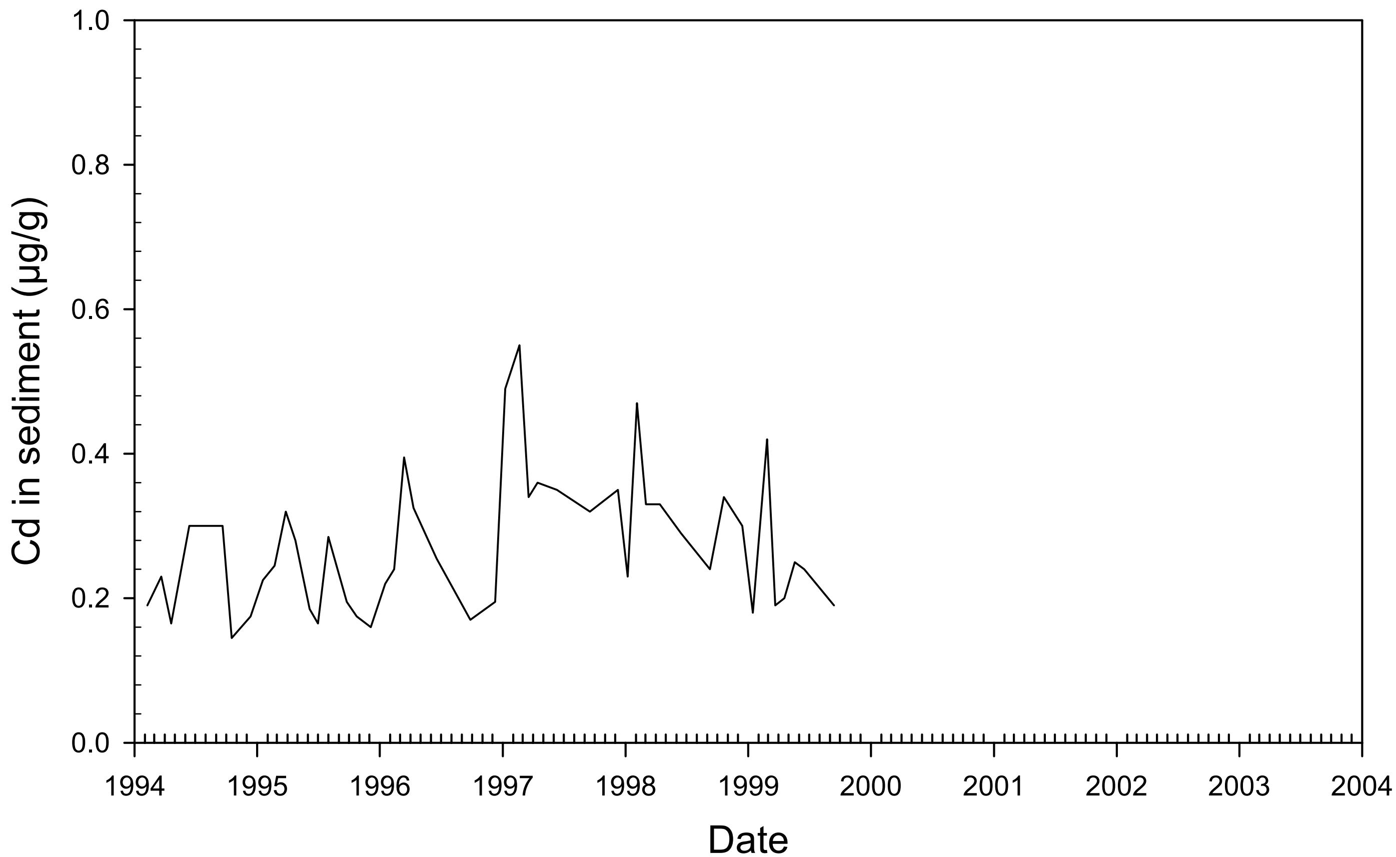
Tissue Analysis:

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
LOD	0.0004	0.0001	0.002	0.004	0.001	0.004	0.002	0.001
LOQ	0.002	0.0007	0.01	0.02	0.003	0.01	0.003	0.006

* All numbers are in units of μg/ml

Appendix G.

Near-total cadmium concentrations in sediments at Palo Alto from 1994 through 1999. (F-2). Sediment concentrations of cadmium (Cd) were slightly elevated from 1997 through 1999 compared to earlier years; although overall concentrations were lower compared to projected biological effects thresholds (1.2 µg/g) (Long *et al.*, 1995) (Figure 8). Also, there appears to be a general decreasing trend over the last three years (1997-1999).



1.0
0.8
0.6
0.4
0.2
0.0
Cd in sediment (µg/g)
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Date